SCHOOL SCIENCE AND MATHEMATICS

VOL. XXXIV, NO. 6 JUNE, 1934 WHOLE NO. 296

NEWTON'S BLIND APOSTLE

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Finis coronat opus. And yet too often a brilliant end overshadows and obscures the struggle of the almost hopeless beginnings. We see astounding accomplishments. These so dazzle our vision that we fail completely to appreciate the labors and painful efforts expended to surmount difficulties which result in realizations only after some friendly and interested hand points the way past these obstacles. Such were the beginnings of Doctor Nicholas Saunderson.

He was born near Penniston in Yorkshire, England, in January, 1682, into a family of moderate circumstances. His father had a place in the Excise for over forty years and possessed a small estate. Vision was granted the child but for twelve short months when smallpox deprived him not only of his sight but even of his eyes. Surely light and color seen for so brief a time could afford him as little idea of them as if he had been born blind. In later years his blindness was partially compensated by the development of a keener sense of touch and of an uncanny intuition of the relative proportions of a room or the distance of objects and persons. He had but to walk into a room to estimate its size or the positions of the objects within it.

During his boyhood he attended the Free School where he applied himself so assiduously to Greek and Latin that he was able to understand Euclid, Archimedes and Diophantes read in the original. His partiality to Horace and Virgil made his recipient mind a veritable storehouse for their most famous pas-

sages, which he quoted freely in the course of conversation. Neither was Tully unfamiliar to him. Besides being able to dictate in Latin fluently he acquired an equally proficient knowledge of French.

After his Grammar School education was completed his father assumed the rôle of instructor of arithmetic. Here his genius readily took root and throve in such favorable soil. In a comparatively short time he was able to do common exercises, perform extended calculations and formulate new rules to simplify complex, perplexing material. His fellow pupils soon discovered his ability and sought his assistance in preference to that of their master.

The next friendly hand was offered him at the age of eighteen years by one Richard West, Esq., of Underbank. He proved a friend indeed, for he possessed two requisites most essential to the ambitious Nicholas. They were wealth and a sincere love of mathematics. This patron appreciated the boy's uncommon capacity and generously instructed him in the elements of algebra and geometry, giving him ample scope for the employments of his talents. Not long after Doctor Nettleton was added to his list of the benefactors who assisted him in his studies. Both undertook to furnish him with the necessary books and gave freely of their time to expound them. It is not surprising then that his thirst for knowledge grew until he outdistanced his instructors.

It became evident that something had to be done to satisfy his eagerness to learn. His father thereupon sent him to a private academy at Attercliff near Sheffield where he began the study of logic and metaphysics. As neither of these subjects were to his liking or taste, he soon withdrew from the school.

At home he pursued his studies in his own way. The need of a good tutor and some one to read to him proved too much of a financial burden to his parents. His ambition centered on entering the University of Cambridge. A university career, however, was far too expensive and the time required for securing the coveted degrees which would qualify him as an instructor and give him the means of self-support was entirely too long. His friends, therefore, resolved to secure for him a mastership in mathematics. If this failed they proposed to open a school for him in London. Accordingly in 1707 Mr. Joshua Dunn received him into his house. He was permitted to assist in the teaching of Philosophy, but was not admitted as a real member of Christ's College where his newest benefactor was a Fellow-Com-

moner. Nevertheless he had the use of the library and every possible privilege accorded him. A Mr. Whiston who held the profesorship of mathematics interested himself in the young man. In his good-natured and generous way he read lectures in a manner proposed by Mr. Saunderson. This interest coupled with Mr. Dunn's untiring advertisement of the character and knowledge of so extraordinary a young man attracted many. Men of learning and others from mere curiosity sought his acquaintance. Lectures given by him were attended by many from other Colleges. The crowd desirous of his instructions grew so much that he did not find the day long enough to divide among them all. Few there were who wished to pursue the more advanced studies, but many who eagerly absorbed the elements of philosophy and mathematics.

Several years before when Newton had left Cambridge, he had already published his *Principia Mathematica.* In this work as well as in his *Optics* and *Arithmetica Universalis* Newton assumed that the readers were well grounded in the fundamentals of mathematics and science. Since, in general, the preparation which would have warranted such an assumption was not adequate these works apparently were destined to take their places among the other learned works which antedated the period in which they would be fully understood and appreciated. Fortunately these became the foundations of Saunderson's lectures, the success of which proved his genius. The enthusiasm with which Newton's works were studied certainly could not escape the notice of the author himself. The master and the disciple met. What must have been Saunderson's satisfaction when on this and subsequent meetings Newton graciously explained many of the more difficult passages.

Henceforth Nicholas Saunderson became an authority in the field of mathematics and science. Halley and De Moivre even regarded his friendship as a real privilege and showed their esteem for him by seeking his advice concerning their plans, ambitions and works.

By 1711 this confidence in his ability had grown to such an extent that when the chair of Mathematics was vacated by his former benefactor, Mr. Whiston, all attention turned toward Saunderson as the one person best fitted to fill that position.

Upon the removal of Mr. Whiston from his Professorship, Mr. Saunderson's Mathematical Merit was universally allowed so much superior to that of any Competitor in the University, that an extraordinary step was

taken in his Favor, to qualify him with a Degree, which the Statutes require. Upon application made by the heads of the Colleges to the Duke of Summerset, their Chancellor, together with the Intercession of the Honourable Francis Robartes, Esq., a Mandate was readily granted by the Queen, for conferring on him the Degree of Master of Arts. Upon which he was chosen Lucian Professor of Mathematics in November, 1711. During the whole transaction Sir Isaac Newton interested himself very much in his Favour.[1]

In 1723 he married the daughter of Reverend Mr. W. Dickson, Rector of Boxworth in the County of Cambridge. Five years later he received the degree of Doctor of Laws from the hands of King George, the Second, upon the occasion of his royal visit to the University.

Since receiving his first degree he expended so much of his time and energy on the demands of his students that little or no time was left for his friends who felt most keenly the lack of his inspiration. Furthermore such close application proved devitalizing. After occasional complaints about a gradually increasing numbness in his limbs, finally though fruitlessly he sought medical attention. He died on the nineteenth of April, 1739, in the fifty-seventh year of his age.

This fatal illness had not been his first serious indisposition. Sometime before he had suffered from a fever which caused alarm among his friends. They then realized that he might be snatched from their midst without having left a single record of his works, lectures and methods. Their timely importunity resulted in the compilation of his *Elements of Algebra*. This was not published until after his death.

This blind instructor had devised many methods for rapid calculations. One of the boards on which he could perform the fundamental operations more rapidly than any one else could with the pen was deciphered by his successor. It consisted of

a smooth, thin board, something more than a foot square raised on a small frame so as to lie hollow, resembling an Abacus. It was divided into a great number of parallel lines equidistant from one another and by as many at right angles to them. Every square inch was divided into one hundred little squares. At every point of the intersection was a small hole capable of receiving a pin. He used two sorts of pins, a larger and a smaller one; at least their heads were different and might be easily distinguished.

A great pin in the center of a square designated a cypher. When two was expressed the cypher remained in place and a smaller pin was put just above it. To express unity the large pin was replaced by a smaller one. The number four brought the small pin descended and followed the cypher. Five was expressed by a little pin in the lower angle to the right. For six

[1] Nicholas Saunderson: *Elements of Algebra*, London, 1740, "Memoirs of the Life and Character of Professor Saunderson," pages vi and vii.

the little pin retreated until just under the cypher. A small pin just before the cypher meant eight and one in the upper left hand corner, nine. (See figures 1 and 2.)[2]

It may be interesting to note that after two was formed by placing the small pin in the hole just above the large pin, each consecutive digit was formed by moving the small pin into each consecutive hole, going in the clockwise direction as is demonstrated in the following figure.

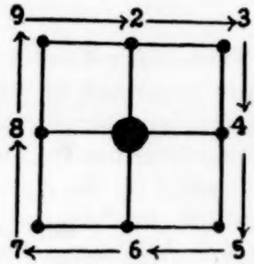

Figure 1 is the key to the numbers and figure 2 represents some of the numbers of more than one digit.[3]

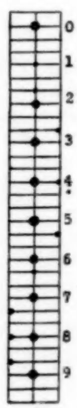

Fig. 1

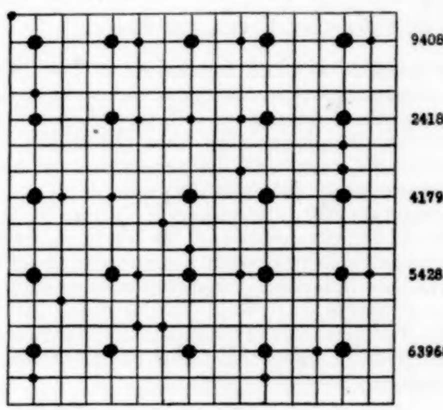

Fig. 2

We find the Author of *The Elements of Algebra* to be very explicit and accurate in his exposition. His one aim was to remove all doubt from the minds of the students, thereby preventing discouragement and even retardation in their progress. Though Saunderson made no notable contribution to the advancement of mathematics, he left a two-fold legacy in the example of his untiring application of the great art of teaching and his unselfish appreciation and admiration of the immortal Newton.

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[2] Ibid., "Nicholas Saunderson's Palpable Arithmetic Decyphered," p. XX.

[3] Ibid., Introduction, fronting page 24.

GENERALIZATION IN ELEMENTARY SCHOOL SCIENCE

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There is considerable controversy at the present time among those interested in elementary school science as to whether children should generalize and to what extent generalization should be permitted and encouraged. This discussion has been intensified by the recent appearance of the Thirty-First Yearbook of the National Society For The Study of Education. Part I, A Program For Science Teaching.[1] Herein it is urged that generalization should occupy a prominent place in the science work of all elementary school children. But there are those who disagree with the position of the Yearbook Committee. For example, Freeman[2] says:

> Another question is more fundamental. The (Yearbook) Committee concludes from current psychological theory that the child's mental development is gradual rather than saltatory. From this it concludes a somewhat different principle, namely, that the child's mental operations are the same at various ages and that, therefore, the kind of scientific study which is appropriate is precisely they same at all ages. In other words, generalizing should occupy as prominent a place in the study which the young child makes of the phenomena of the world about him as it does in the study carried on by older persons. I am not at all sure that this is the case. At any rate I do not believe that we have enough evidence to make us sure of this sweeping statement. To the young child phenomena may be more nearly just phenomena—happenings. There may be more place for the wide eyed watching of the drama of life without for the moment inquiring too deeply into its explanation.

Now the term "generalization" is being used in two distinctly different senses which are seldom differentiated in discussions. The Thirty-First Yearbook[3] presents, as a basis for a program of instruction for elementary school science, thirty-eight statements or "Large Generalizations." And some have thought that children were to learn these statements and that they generalized when this was done.

In this sense generalization is conceived of as a single formal statement; a final step of mature thought.

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[1] National Society For The Study of Education. Thirty-First Yearbook, Part I. A Program For Teaching Science. Public School Publishing Company. 1932.

[2] Freeman, F. N. Comments On The Program For Teaching Science From the Psychological Point of View. Science Education. Vol. 16. No. 4. April 1932.

[3] Pp. 53–55, op. cit

But generalization is also conceived of as a constant process in the thought movement. A thought movement which may however be directed toward an understanding of such mature end products of thought as are termed generalizations in the first sense. Dewey[4] states the position thus:

> Generalization is not a separate and single act; it is rather a constant tendency and function of the entire discussion or recitation. Every step forward toward an idea that comprehends, that explains, that unites what was isolated and therefore puzzling, generalizes. . . . The factor of formulation, of conscious stating, involved in generalization should also be a constant function, not a single formal act.

Obviously, the teacher's and curriculum worker's conception of generalization would radically influence thought and practice.

In order to aid in clarifying this question and to secure some objective data concerning how children learned such "objectives" or "generalizations" as proposed in the Thirty-First Yearbook a carefully controlled study was made throughout the first six grades of an elementary school.[5] Phenomena or happenings were presented to children and their generalizations in terms of an objective[6] were secured. Many different happenings or phenomena were presented to these children as situations for the purpose of securing their interpretative reactions. One type with accompanying generalizations will be given here for illustration. The phenomenon was that of the turning of a green plant toward the light. The illustrative generalizations here given are the most complex (as judged by criteria developed in the study) made on each of the six grade levels.

The examples which are given show that these children generalized on all six of the grade levels studied. The generalizations which were made on the lower grade levels were less complex than those made on the higher grade levels but they were all in such terms of the objective as were within the experience of the children. On the first grade level the generalization involved only the concept of *strength*. On the second grade level *food making* appears. On the third grade level the concept *food making* is associated with *food loss* and *change of color*. On the fourth grade level *green leaf* is associated with *little machines*

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[4] Dewey, John. How We Think. D. C. Heath and Company. 1910.

[5] "An Experimental Application of A Philosophy of Science Teaching." To be published as a doctor's dissertation by the author. Teachers College, Columbia University.

[6] The objective was "The Sun Is The Chief Source of Energy For The Earth." This is adult terminology. It was the teacher's criterion for the selection and organization of learning experiences for every grade level. The illustrative statements of interpretation which follow are the children's words.

and *food making*. On the fifth grade level to the concept of *food making* are added *food storage* and function of *soil and water*. And on the sixth grade level concepts of *chlorophyll, machines, sun energy, food making, food storage* and *stem and leaf* are associated.

THE FIRST GRADES

Observation or Happening	*Generalization or Explanation*
Plants turn toward the window.	Plants bend to the window to get light because light makes them strong.

THE SECOND GRADES

Plants turn to the window to get light.	Plants get yellow and die in the dark because they have no light to make food.

THE THIRD GRADES

Plants bend to the window to get light.	In the dark the plant would lose all of the food in it and then get yellow and die.

THE FOURTH GRADES

Plants turn toward the sun.	If you put a plant in the dark it will not have green in its leaves because the little machines that make food for the plant stop working.

THE FIFTH GRADES

The plant follows the sun.	A plant in the dark with plenty of good soil and water would never live unless it had been in the sunlight and had stored up a little food with which it could live for awhile.

THE SIXTH GRADES

Plants turn toward the light.	The chlorophyll (or green color) in the leaves acts like a machine, and through the energy of the sun makes food which is stored in the stem and leaves of the plant.

The difference between the mental operations of the children of the first and sixth grades was not one of ability to generalize. The difference was one of complexity of the generalizations which were made.

In this study these children's observations and generalizations interpenetrated. Is not this the case in all natural child

learning? If so, teachers should not attempt to reserve for higher grade levels that segment of a child's thought movement which is concerned with their interpretations.

But granted that children of all grade levels generalize and should generalize, there are two critical factors involved when children are brought under formal instruction. And from study of these factors will come a solution to the fundamental problems of child generalization.

The first consideration is the time, in any given lesson, when generalization is best introduced or formulated. In some situations generalization is most effective when introduced at the very beginning of the lesson or unit; as a basis for interpretation of ensuing observations. In other situations it is most effective near the middle of the lesson; as explanation of observations already made and a basis for those which are to follow. In still other situations generalization may best wait until the very close of the lesson; until many observations have accumulated.

The second consideration, equally as important as the first, is the phraseology of the generalization. It is here that many abuses are made by teachers. Here the "psychological talent"[7] is sorely needed. Words may impede learning as effectively as they may promote it.

The question is not whether children should generalize. It is rather when, in any lesson, the process should take place and the manner in which the formulation should be made.

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[7] Koffka, K. The Growth of the Mind: an introduction to child psychology. N. Y. Harcourt, Brace.

A STUDY OF THE EFFECT OF A COURSE IN HIGH SCHOOL BIOLOGY ON PERFORMANCE IN COLLEGE BIOLOGY

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MATERIALS AND METHODS

One rather frequently hears from the lips of college instructors, especially in the sciences, an expression of doubt as to the value of high school science as a preparation for college work, and occasionally some instructors will go so far as to say that the science work in high school is prejudicial to satisfactory work in college.

It is to be recognized that the avowed aims in high school frequently have little to do with college preparation, and this is perhaps more true of biology than of any of the other sciences. Nevertheless, it would seem reasonable to expect that there is considerable value in a well arranged and satisfactorily taught course in high school biology, and that these values become evident in the college classes. On the other hand it is to be recognized that there are a variety of courses in *biology* taught by teachers of all degrees of training and interest; and so one expects to secure all sorts of results in any attempt at an analysis of the effect of the high school course on college performance.

In order to subject the above mentioned opposing "feelings" (they are little more) to an analysis, questionnaires were prepared, which were filled out by our elementary course students indicating whether they had presented entrance units in high school biology; and the grades made by these students in elementary biological courses in college were then plotted against the information obtained from the questionnaire.

The data at best are not wholly satisfactory and there are many factors which have not been taken into consideration, largely from a lack of time and a broader vision of the problem at the time of its inception. There are two very serious faults in our data. First: the relative performance of the student in other subjects has not been secured and correlated with the grade in biology. Second: the number of students available for the study are not sufficient in number to warrant final conclusions, especially in certain brackets. However, on the whole, the results obtained seem to be fairly acceptable as an indica-

tion of what one might expect in a more complete analysis.

The information gathered in this questionnaire bears upon other mooted questions such as: does the prospect of a career based upon biology, such as medicine or forestry, have any bearing upon performance in this subject; are Northern students better prepared for work in biology than Southern; does it make any difference whether laboratory work is individual, group, or demonstration, or if it is altogether lacking? Suggestive data as to these questions are to be presented for consideration.

The data included herein were secured in Duke University; for three years in Zoology and two years in botany, the study being based upon about 700 students in zoology and more than 350 students in botany. Naturally, the analysis of the zoological data has been more complete.

DOES HIGH SCHOOL BIOLOGY AFFECT COLLEGE PERFORMANCE?

We shall consider first this question; What effect does high school biology have on college performance in biology?

Perhaps the question should be modified so as to read college zoology and botany, since in the institution where this study was made the courses are separated. Table I gives the material bearing upon this question as related to zoology.

Even a cursory examination of the data indicates that the student who has taken high school biology is much more likely to make an A or B than one who has not had such a course. The following tabulation indicates the combined results of the three year study.

ZOOLOGY

(1) Total Students presenting High School Biology 426
(2) Total Students not presenting High School Biology 247

Percentage	Making	A	B	C	D	F
of (1)		6.1	20.6	50.7	14.3	8.7
(2)		3.7	16.6	47.7	21.0	11.7

It must not be concluded however that the failure to take high school biology prohibits a student from making a top grade; and possibly one should expect a much wider difference in performance than is indicated in this study.

The data as to the relationship to performance in college botany are assembled in Table II. The difference here is also in favor of the student who has had H. S. biology, but it is not so striking as may be seen in the following tabulation which summarizes the results for the two-year period.

Table I: Zoology

Grade		H. S. Biology				Kind of Laboratory								Pre-Medical	
		Yes	%	No	%	A	%	B	%	C	%	D	%	Yes	No
A	1931	8	5.8	0	0	3	7.2	0		5	5.3	0		5	3
	1932	11	7.6	4	5.3	3	7	4	9.5	4	6.8	0		11	4
	1933	7	4.8	3	3.4	0	0	3	6.8	2	2.4	1	20	8	2
B	1931	36	26.2	15	18	8	19	0		27	28.7	1	33	30	21
	1932	24	16.7	13	17.3	8	19	6	14.3	10	17	0		15	21
	1933	28	19	13	14.6	8	22.8	10	22.7	10	17.2	0		18	23
C	1931	68	50	34	41	23	56	0		43	45.7	2	66	52	50
	1932	69	48	37	50	22	52.3	17	40.4	30	50.8	0		34	73
	1933	76	52	47	52.8	24	70	23	52.3	28	48	1	20	65	58
D	1931	13	9.4	26	31	2	5	0		11	11.7	0		12	27
	1932	27	19	11	14.6	7	16.7	10	23.8	10	17	0		15	24
	1933	22	11	15	16.8	2	5.8	5	11.3	11	17.2	2	40	17	20
F	1931	13	9.4	8	9.6	5	12.2	0		8	8.5	0		11	10
	1932	12	8.3	10	13	2	5	5	12	5	8.5	0		8	11
	1933	12	8.3	11	12.3	1	2.8	3	6.8	7	12	1	20	9	17
Total	1931	138		83		41		0		94		3		110	111
	1932	143		75		42		42		59		0		83	133
	1933	145		89		35		44		58		5		117	120

A indicates individual work; B, work in groups of 2–4; C class demonstration; D, none.

(1) Total Students presenting H. S. Biology........................225
(2) Total Students not presenting H. S. Biology...................126

BOTANY

Percentage	Making	A	B	C	D	F
of (1)		2.6	20.8	36	30.2	10.0
(2)		3.2	15	31.7	38	12.0

The failure of high school biology to affect college performance in botany in a manner comparable to that in zoology may be due either to the content or to the methods of the high school courses, which, because of civic and health interests, may lean more to zoological materials.

The fact that the percentages of failures are so nearly the same for those having taken biology and those not, in Table I (zoology) and Table II (botany) indicates that some schools are giving exceedingly poor courses in biology; and further analysis may discover the particular deficiency.

On a basis of the data for both zoology and botany one is forced to conclude that a high school course does have an effect on college performance—and doubtless if all high school courses of biology were of a high standard the difference would be remarkable. In all cases it is to be remembered that the college course is given on a Freshman level and does not presume preliminary training.

DOES THE TYPE OF HIGH SCHOOL LABORATORY WORK AFFECT COLLEGE PERFORMANCE?

Comparatively few schools teach biology from the textbook alone; in our records only ten students of the 650 who offered zoology had had a course without laboratory work. These cases are too few to be considered.

Data is available however as to the effect of the various types of laboratory work. These have been assembled in Table I for zoology and in Table II for botany. The summarized data for the three-year period in zoology is as follows:

ZOOLOGY

(1) Number students reporting individual lab. work	118
(2) Number students reporting 2–4 lab. work	86
(3) Number students reporting demonstration lab. work	211

Percentage	Making	A	B	C	D	F
of (1)		5	20	58	9	6.8
(2)		8	18.6	46	17.5	9.3
(3)		5	22.2	47.8	15.1	9.5

Table II: Botany

Grade	H. S. Biology				Kind of Laboratory							
	Yes		No		A		B		C		D	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1932 1933 A	3 3	2.7 2.6	3 1	4.1 1.9	0 1	0 6.3	1 0	2.8 0	2 0	4.2	0 0	
B	18 19	16.5 25	11 8	15 15	7 6	28.0 37.5	4 9	11.2 18.4	7 12	14.6 25.5	0 2	 100
C	33 48	30 41.9	19 21	26 40	9 6	36.0 37.5	14 22	39.2 44.5	10 20	21.0 42.5	0 0	
D	41 27	37.6 23.2	30 18	41 34	7 3	28 18.7	13 16	36.4 32.6	21 8	43.7 17	0 0	
F	14 9	12.8 7.7	10 5	13.7 9.4	2 0	8 0	4 2	11.2 4	8 7	16.6 15	0 0	
Total	109 116		73 53		25 16		36 49		48 47		0 2	

A indicates individual laboratory work; B, work in groups of 2–4; C, class demonstration; D, none.

The difference is not as favorable to individual work as some of us might wish in the higher brackets, but is quite so in the medium and lower groups. The high rating of the "demonstration" group may be due to the feeling of responsibility which rests upon the instructor in this type of teaching.

The summarized data bearing on this point as related to botany follows:

Botany

(1) Number of Students reporting individual work	41
(2) Number of Students reporting 2–4 work	85
(3) Number of Students reporting demonstration work	95

Percentage	Making	A	B	C	D	F
of (1)		2.4	31.7	36.6	24	4.8
(2)		1.2	15.3	42.3	34	7.0
(3)		2.1	20	31.5	30.5	15.8

From these data it is quite evident that the individual laboratory work in the high school is of decided advantage, and in certain ranges the 2–4 grouping is superior to demonstration.

DOES A PROPOSED CAREER AFFECT COLLEGE PERFORMANCE?

It is often remarked that certain groups of students perform better because they have definitely decided upon a career, and certain courses point toward that career. An example of this is to be found in elementary zoology which is foundation work for the pre-medical student. The data on this point are to be found in Table I. The summary for the three-year period follows:

	Total	Percentage Making				
		A	B	C	D	F
Pre-medical	310	7.7	20	49.3	14.2	9
Non pre-medical	364	2.2	17.8	50	19.6	10.4

These data indicate that the pre-medical student performs better than the non-pre-medical student in general zoology, and that a definite career does have a bearing upon performance in courses which the student believes (however erroneously) are a preparation for his career.

COMPARATIVE PERFORMANCE OF STUDENTS PREPARED IN NORTHERN AND SOUTHERN HIGH SCHOOLS

It is rather commonly heard that Southern students are less properly prepared than Northern students. If such is the case, it seems reasonable to suppose that it would be reflected in college performance. For valid conclusions it is necessary that the

groups studied should be comparable and that a similar procedure of selection for admission to college should be followed. In such a study it would also be desirable to eliminate all but Freshmen. The first is met perhaps as well at Duke University as in any institution in so far as zoology is concerned. The data on this point are assembled in Table III for zoology and in Table V for botany. For the three year period the data for zoology summarizes as follows:

		Percentage Making				
	Total	A	B	C	D	F
North	337	3.8	17.2	52.8	18.7	7.4
South	330	5.7	21.2	45	17	11

The higher brackets are distinctly favorable to the South, while the F bracket is distinctly against the South.

A factor, which would have a bearing on this question is undeterminable; namely—the bases of selection, especially of Northern students, which the writer believes are more rigorous than for the Southern student, and the North Carolina student in particular.

In other words, the policy of selective admission recommended by the Duke Indenture is naturally applied less rigorously to the students drawn from the traditional territory of the institution than to students drawn from other areas. A comparison of the records of North Carolina students with a more or less comparable number from Northern states might shed some light on this subject. In order to secure as uniform a group as possible for comparison, the students from New York, Pennsylvania, and New Jersey were taken collectively. The number of students from these three states for 1931 and 1932 approximates that of North Carolina. The summarized data for those two years follows:

		Students Making				
	Total	A	B	C	D	F
North	142	8	28	74	27	5
South	144	6	36	56	32	14

In the fall of 1933 both New York and Pennsylvania each furnished a number of students comparable to those from North Carolina. The data follow:

		Students making				
	Total	A	B	C	D	F
New York	31	1	6	14	7	3
Penn.	36	1	5	16	9	5
N.C.	35	2	9	17	4	3

From these data we must conclude that either we are accepting poorer students from the North or we are getting better students from the South. The comparative data for three years indicates the latter to be the proper interpretation.

The data on this point in relation to botany were secured for 1933 only. These indicate an advantage to the South as shown in the following table:

	Students making				
	A	B	C	D	F
North	3	13	35	23	7
South	1	24	35	23	7

PERFORMANCE AT DIFFERENT COLLEGE LEVELS

Departments are often criticized for placing their courses on a level too high for the natural candidates, and therefore produc-

TABLE III

Grade	Year	Class in College				North		South	
		1	2	3	4	No.	%	No.	%
A	1931	5	2	0	1	4	5	4	3
	1932	10	4	1	0	6	6	8	8
	1933	4	5	1	0	3	2	7	8
B	1931	36	7	7	1	18	20	33	36
	1932	20	12	3	0	17	16	21	19
	1933	27	10	1	1	23	16	16	18
C	1931	63	25	12	2	48	53	57	44
	1932	60	32	10	2	56	54	44	39
	1933	88	26	7	0	74	52	47	52
D	1931	24	9	4	2	17	19	21	17
	1932	25	12	4	0	20	19	24	21
	1933	31	6	0	0	26	18	11	12
F	1931	15	4	2	0	3	3	13	10
	1932	10	7	1	0	5	5	14	13
	1933	21	2	1	0	17	12	9	10
Totals	1931	143	47	25	6	90		128	
	1932	125	67	19	2	104		112	
	1933	171	49	10	1	143		90	

ing too high a percentage of failures. This doubtless happens often, but does not seem to be the rule in biological sciences.

The data which have been assembled in Table III indicate that most of the students in the freshman class are in the C brackets, (strangely enough this was true also of sophomores, juniors and seniors), and the others are distributed in such a fashion as to make a reasonable, but not necessarily ideal curve.

Since nearly half of the freshmen make C, it does not appear as if the course were on a level too high for them and the rela-

TABLE IV: ZOOLOGY*

Grade	Year	Men		Women		Total
		No.	%	No.	%	No.
A	1931	6	3.6	3	4.3	9
	1932	14	9.2	1	1.4	15
	1933	9	5.2	1	1.5	10
B	1931	37	22.4	15	21.7	52
	1932	27	17.9	10	13.5	37
	1933	29	17.0	12	18.0	41
C	1931	77	46.6	29	42	106
	1932	74	49	36	48.6	110
	1933	87	51	35	52	112
D	1931	29	17.6	15	21.7	44
	1932	23	15.2	18	24.3	41
	1933	24	14.0	14	21.0	38
F	1931	16	9.6	7	10.1	23
	1932	13	8.6	9	12.2	22
	1933	22	12.8	5	7.5	27
Total	1931	165		69		234
	1932**	151		74		225
	1933	171		67		238
		487		210		

* Data includes only such students as remained in courses to exams.
** Slump in '32 due to method of registration.

tively poor performance of juniors and seniors seems attributable to a lack of interest, or the necessity of taking a typical freshman course.

COMPARATIVE PERFORMANCE OF MEN AND WOMEN

It has become quite customary to advise women who wish to take biology, to register for botany since it is believed by some that their interests, or even their minds are more adapted to that subject; while men are more often advised to study zoology for similar reasons. The data for the relative performance of men and women in zoology is given in Table IV, and for botany in Table V.

TABLE V: BOTANY

Grade	Year	Men	%	Women	%	Total	%	North	South
A	1932	3	3	3	3.3	6	3.1	*	*
	1933	2	3	2	2	4	2.3	3	1
B	1932	8	8	23	25	31	16		
	1933	16	22	21	22	37	22.1	13	24
C	1932	19	19	35	37	54	27.8		
	1933	22	31	48	49	70	41	35	35
D	1932	49	48	28	30	77	40		
	1933	26	36	19	19	45	26.4	23	23
F	1932	22	22	4	4.7	26	13.3		
	1933	6	6	8	8	14	8.2	7	7
Total	1932	101	100	93	100	194			
	1933	72		98		170	100.2	81	90

* North and South Distribution was not determined for 1932.

The total number of students in 1933 in this table does not agree with that in Table V since for the latter information blanks were missing for a few students.

For zoology the data for the three years may be summarized as follows:

		Percentages making				
	Total	A	B	C	D	F
Men	487	6	19.2	49	18	8.5
Women	210	2.4	17.7	47.7	22	10

While the men show a better record, it must be remembered that nearly half of them are pre-medics functioning at a higher level. Our data do not admit a careful analysis of the subject but they indicate that the level of performance for women and non-pre-medical men is about the same.

The data for botany shows a superior performance by women, but it is doubtful if the data are sufficient to settle this point. These may or may not mean that women are more interested in botany than men. It does not however prove that women's minds are more adapted to botany since in this institution women are probably much more carefully selected than men, because the University makes provision for less than a third as many women as men.

In any case it seems doubtful to the writer that there is any evidence that woman's mind is especially adapted to botany, and a man's mind to zoology.

CONCLUSIONS

The data submitted here seems sufficient to justify the following conclusions:

1. A high school course in biology does have a beneficial effect on one's performance in college zoology, provided the course has been pursued in our better schools. The beneficial effect on botany, while present is not as evident from our data.
2. Individual laboratory work is preferable to demonstration while intermediate size groups are less desirable than either individual or demonstration, doubtless due to the fact that in many cases the grouping of 4 or more is a make-shift procedure, while for demonstration more serious preparation is made by the teacher.
3. Southern schools, while furnishing more failures, still furnish their full quota of better students. This is true of North Carolina schools, specifically.
4. As one might expect, professional outlook affects college performance in zoology favorably.
5. The relative performances of men and women in zoology or botany does not seem to differ materially, other things being equal.

TEXTILE PRINTING AND DYEING WASTES EASILY MADE HARMLESS IN WATER

Pollution of rivers and other bodies of waters by at least one type of industrial wastes, the discards of the textile printing and dyeing industries, can be easily and cheaply avoided. Foster D. Snell, Brooklyn consulting chemist, pointed out to the American Chemical Society how these waste liquors can be made harmless to fish and plant life in streams by adding to every thousand gallons four pounds of copperas and four pounds of lime, at a total cost of less than five cents for each thousand gallons.

—*Science Service*

IMPROVED SCIENCE TEACHING

BY ELLIOT R. DOWNING
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There is a crying need for a marked improvement in the teaching of science in the schools. We have only made a beginning in the accomplishment of the valuable outcomes that may be achieved by such instruction. Betterment is primarily dependent on two things—an improved curriculum and better trained teachers.

The curriculum needs to be unified. At present we have a series of unrelated fragments of science in the curriculum—nature study or elementary science, general science, biology, physics, chemistry. They are largely uncorrelated and the series has little if any dependent continuity. We need a curriculum that will definitely prescribe the outcomes to be achieved at each grade level—the habits to be established, the skills to be acquired, the ideals, tastes and attitudes to be achieved, the principles to be mastered. Then there must be rigid adherence to certain prerequisites. The pupil must have accomplished the prescribed outcomes of elementary science before undertaking general science. The achievements set up for general science must be prerequisite to the later sciences. And there should be intimate correlation between biology, physics and chemistry.

The curriculum should be stated in terms of the things to be accomplished and not in terms of the subject matter to be studied. The latter may be suggested but the prime emphasis needs to be placed on the outcomes to be achieved. Many a teacher of science is now busy cramming the heads of pupils with the subject matter in the textbook—with no clear idea as to what educational ends are to be accomplished thereby—without, in many cases, achieving any that are really of value.

There must be prescribed for each grade the habits to be established, the skills to be achieved, the emotionalized standards to be imparted and the principles to be mastered. These things should be taught for keeps and not require reteaching. Teacher and supervisory officer will then know where the responsibility rests for each of the items of the curriculum. Such a curriculum will prescribe only a few items for each grade for teaching to the point of mastery takes time. Much drill is

necessary. But it will result in real learning, not the useless smattering of information which now is largely the outcome of science instruction.

We are trying to cover too much ground at each level of instruction. This is well illustrated by the dissatisfaction of college teachers with the preparation achieved in their particular subjects by the high school instruction. They say that students who have had physics, chemistry, etc. in high school do no better in the college classes in these subjects than do those who have not had them, and they back up their opinions with tabulations of grades that justify their opinion.

And yet they do not realize that the colleges are largely to blame. The college entrance examinations in these subjects demand a knowledge of the field of physics, of chemistry, etc. And the field can not be covered in a year. The average high school text in physics treats, for example, forty-three different principles and, in addition, uses more than half its space to give a mass of unrelated facts. Mr. Benjamin's study shows that it takes at least two weeks to teach a principle of physics to the point of mastery—that is, so it can be applied to problems of the sort that arise in life. It is mathematically impossible to teach forty-three principles in the time allowed for their study.

The solution of the difficulty would seem to be to master a very few of the less abstract principles in elementary science, a few at the general science level, say ten or a dozen more in high school physics and leave the rest for college and university classes. Then the college teacher could depend on pupils knowing—not physics—but a small part of it thoroughly well. He could go on from that point.

It seems self-evident that those principles of science needed most frequently by Mr. Everyman in solving the problems he encounters in life are the ones that should be taught in the public schools. And much exercise should be given in their application to such problems. In other words, the science taught as a part of the general culture course, even that in college, should be consumer science as distinct from producer science. Producer science is for the scientist. He needs to survey the whole field of his specialty, to be trained in inductive thinking, the method of the discoverer. Mr. Everyman needs only the science that will help him solve his problems that are scientific in character whether those problems are of the sort that involve

some practical action on his part or those he solves merely to satisfy his intellectual curiosity. He needs training in deductive thinking—the method of applying known science principles. What principles are the most important—the ones most often needed in life situations—has been to some extent determined by objective studies (See theses of Sites, Nuser, McDaniel, Harris, Watson, Richardson, Weber, Jones, Markland, etc.)

It would seem as if training to think scientifically should be one of the major goals of science instruction. For the scientific method is essential to the correct solution of life's problems, even those that are not scientific in character.

John Dewey claims that science as method is more important than science as subject matter in our modern life. The author has elsewhere shown (*Science Education*, XVII, April, 1933, 87–89) that the results of tests in scientific thinking indicate that those pupils who have had much science in high school are no more skilful in scientific thinking than are those who have had little or none. This is not surprising for little or no effort is being made by science teachers to impart such skill. Perhaps it is safe to say that few of them know what are the elements of the skill. Yet, if Dewey is right, here is an important job which science teaching has not yet seriously tackled,—a chance for vast improvement in our teaching of science.

Since textbooks determine in large measure the science curriculum a reform in the latter presupposes a new type of the former. Textbooks to embody the outcomes outlined above are largely yet to be written. They will appear in response to an insistent demand for the more specific objectives of science instruction. Some alert teachers are organizing and mimeographing instructional material along the lines suggested and trying it out in science classes. Such experimental work should soon give some data in regard to the practicability and the techniques of achieving the desired aims. Meanwhile teachers may emphasize the mastery of science principles, give much practice in their application and omit the unrelated and unimportant factual details. They must find outside of textbooks or create instructional material to impart skill in scientific thinking and to develop emotionalized standards for such materials are largely lacking in current texts.

The science teacher for the public schools must be trained, not as a narrow specialist but broadly. The large majority of high schools are small schools employing not to exceed five

teachers. The teacher of science in such schools will teach all the sciences. Even the teacher in the large high school who handles only one science subject must have training in other fields if he is to intelligently correlate his subject with others and if he is to participate effectively in curriculum planning.

The wise superintendent or principal now obtains his science teacher from teacher training institutions which prescribe courses in the several sciences, taught from the point of view of consumer science, and which provide for their graduates, not blanket certificates, but certificates of preparation to teach specific combinations of subjects.

The teacher of science should not only be reasonably well prepared in the subjects he is to teach but also in the technique of teaching these subjects. Teaching is an art based on a mass of scientific educational data approximately as exact though not as extensive as the data in the several science fields. "A man who knows his subject can teach it" is as absurd a statement as its opposite that a man who is a good teacher can teach a subject concerning which he knows little or nothing. The science teacher must be a scientist and a teacher.

He must have clearly in mind the major goals and the more specific objectives to be achieved by his science instruction so that each day's instruction results in a definite outcome which in turn fits into the instructional unit as the unit fits into the course.

He must know how to teach pupils how to learn. For after all, that is his major task, one might almost say his only task. He can not "learn 'em." Whatever his students get they must get for themselves. All he can do is to teach them how. The teacher who assigns lessons for students to get at their seats or at home in their own blundering fashion is shirking his major responsibility. He must teach them how to study. To this end he studies the test papers not merely to see what grade each pupil should have but chiefly to discover what learning difficulties the pupils are encountering. Thus he can modify his teaching techniques to avoid or overcome them.

If the assigned task is largely a memory job, then he should teach pupils how to memorize. If the assignment involves speed and comprehension in reading then he must teach pupils how best to acquire these skills. If pupils are to learn from an experiment then they must be trained to experiment purposefully, to pick out essentials from the mass of irrelevant details, to

arrange data in logical sequence, to draw safe conclusions. If pupils are expected to reason by the method of similarities and differences then they must be taught the proper technique of comparison. Experimental studies have repeatedly shown that when instruction is centered on teaching pupils how to learn the grades achieved are very much higher in the experimental groups than in the equivalent control groups that are not given the benefit of the improved techniques of instruction (See the Master's theses of Leslie Hunt, Alfred Clem, T. D. Fox, W. L. Beauchamp).

UNIFORM CIRCULAR MOTION AGAIN

By G. B. Blair

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Seventeen years ago the writer pointed out in this magazine[1] that most textbooks on elementary physics fail to make clear to the student that the formula for the acceleration in uniform circular motion is an exact and not an approximate formula.

Several years later Professor W. W. Sleator, apparently without having read the earlier article, called attention to the same fact and proposed a proof of the formula which was mathematically rigorous but perhaps a bit difficult for elementary students.[2]

At the present time the writer can name only one or two of a multitude of high-school and college physics texts which are guiltless of the error mentioned above.

What seems a simple and yet mathematically exact proof of the formula in question, is given in the following discussion.

A body moving with constant speed in the circular path $ABCA$, Fig. 1, moves from A to B in t seconds. The velocity at A is represented in both magnitude and direction by the line V_0; also, the velocity at B is fully represented by the line V_t. The only change in velocity which takes place in the time t is a change in *direction* for the *magnitude* (the speed in the path) is the same at B as it is at A.

Fig. 2 shows how V_t may be obtained by combining with V_0 another velocity, V_c. The Velocity V_c, added by vector addition

[1] School Science and Mathematics, Vol. 16, p. 730.
[2] School Science and Mathematics, Vol. 23, p. 112.

to the velocity V_0, produces the resultant velocity V_t. V_c is therefore the change in velocity in t seconds.

Since V_0 in Fig. 2 is perpendicular to AO in Fig. 1 and V_t in Fig. 2 is perpendicular to BO in Fig. 1, the triangles are similar and

$$\frac{V_c}{chord}=\frac{V_0}{r} \text{ or } V_c=\frac{chord \times V_0}{r}.$$

If the velocity chage V_c is divided by the time t the result is the *average* change in velocity per unit time or the *average* acceleration. Note that the velocity change divided by the time is the average acceleration just as the change in position, the

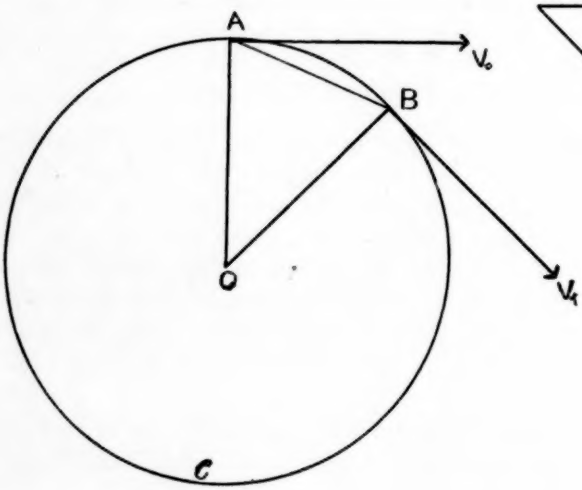

Fig. 1.

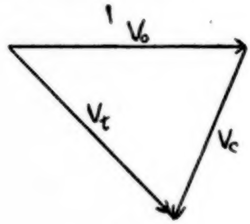

Fig. 2.

displacement, divided by the time is the average velocity. If the direction of motion is changing, as it is in this case, both the displacement and the velocity change are vector quantities. The average velocity for the time t is the chord AB divided by t and the average acceleration is V_c divided by t. We may note also, in passing, that the average *speed*, rate of motion *along* the path, is the distance along the path divided by t or the arc AB divided by t.

Dividing both sides of the last equation by t.

The average acceleration $=\dfrac{V_c}{t}=\dfrac{chord \times V_0}{rt}.$

But the body traverses the arc AB with a steady speed equal

to V_0 (numerical value always the same) so that

$$arc = V_0\, t \text{ or } t = \frac{arc}{V_0}.$$

Substituting in the equation above and simplifying.

$$\text{Average acceleration} = \frac{chord}{arc}\frac{V_0^2}{r}.$$

Now, if B is brought nearer to A the average acceleration is expressed for a part of the path closer and closer to A while the chord and the arc become more and more nearly equal. In the limit, when B reaches A, the chord and the arc are equal and

$$a = \frac{V_0^2}{r}.$$

Where a is the acceleration *at* the point A. Similarly, the acceleration at any other point on the circle may be shown to be

$$\frac{V_0^2}{r}.$$

MATHEMATICIANS HONORED

At the recent meeting of the American Mathematical Society in Chicago, the dinner program was devoted entirely to honoring emeritus professors, Thomas F. Holgate of Northwestern University and Herbert E. Slaught of the University of Chicago. Each had been secretary of the Chicago Section of the Society for a ten-year period and each had served his University continuously for more than forty years. Professor Slaught had been made honorary president for life of the Mathematical Association of America, at its previous Cambridge meeting, in view of his leading part in founding and promoting that association and in reorganizing the American Mathematical Monthly in 1913, which was to become its official journal in 1916. Professor Slaught is also an honorary life member of the Central Association of Science and Mathematics Teachers.

COCKROACHES

By D. G. VEQUIST

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This familiar inhabitant of houses in the warmer temperate zone may well be the object of further investigation. He moves with amazing speed even on the smoothest surface such as glass. He climbs even on glass ceilings. How is this accomplished? If the insect is carefully deprived of moisture his power of glass climbing is lost. Supply him with a drop of water to wet his feet and we have magically changed him to a glass climber. A fish globe with a gauze cover becomes the roach's home where we can study this venerable insect, man's uninvited guest for the last thousands of years.

TEACHING SCIENTIFIC METHOD

Article IV: Teaching the Scientific Method in Mathematics Classes

By Maurice L. Hartung
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One of the most encouraging signs that progress is being made by the teaching profession is the evidence that increased attention is now being devoted to the teaching of broad general principles and to the development of desirable attitudes and ideals. During the last decade or two much study has been devoted to objectives. The attempts to measure the extent to which these objectives are being realized have led to the conclusion that general principles, attitudes, and ideals have been neglected in favor of mere factual information, and that there is great room for improvement in the teaching of these more elusive elements. In this connection it may be noted that the decline in enthusiasm associated with the testing movement is due in part to the fact that most existing objective tests stress factual knowledge. Objectives such as are implied by the phrases "scientific attitude" or "appreciation of the power of mathematics" are tested only incidentally if at all.

Modern psychology acknowledges that "transfer of training" is a sound doctrine but makes plain that the amount of transfer depends upon the extent to which the students are made conscious that the procedure under consideration is general in its application and hence has broad possibilities of transfer. Suppose, for example, the formula is taught as a mere incident of the algebra lessons of a few weeks of the year. When the students study physics and chemistry, or encounter any other situation which calls for the use of the formula, it may well happen that they will show little evidence of transfer. If, however, they are thoroughly impressed with the idea that the use of the formula is a procedure of great generality, then the possibility of transfer is tremendously increased. Among the very broad general principles which the student should absorb is the "scientific method," and this article is one of a series whose purpose is to show how it may be taught by examples taken from the various fields of study.[1]

Modern psychology puts emphasis upon the fact that "trans-

[1] Cf. Davis, Ira C.—*Is This The Scientific Method?* p. 83 ff, this volume. See also p. 233.

fer takes place or not according to the method of presentation and the method of learning that the subjects undergo."[2] Since the amount of transfer is a function of the method of teaching, the question at once arises as to what methods are most effective. While no definite answer may be given to such a question, we can say that the inductive method is a very superior one. The inductive method is the method of discovery—the method of science. From a study of particular examples the general principle is worked out. Since the development of this ability to form generalizations is an important educational objective, opportunities must constantly be provided in which the students may generalize. It is surprising, then, that so few textbooks are written on this plan, and how many times the authors begin by announcing the general rule and proceed to the examples.

The essentials of a good inductive development are well known. It should begin with a period of preparation in which old knowledge is recalled, interest is aroused, and the aim, problem, or question is set up. It proceeds to a period of presentation and comparison during which numerous illustrative examples are studied. These examples must be typical as to essential elements, and varied as to non-essentials. The comparison period is characterized by the formulation of tentative conclusions and generalizations which are verified and modified by further examples until the general conclusion is reached.

Now it is important that during this entire process the pupils be made conscious of this procedure. They should realize that the problem before them is to find the general law. They should understand that they must seek common elements in all the examples, and test their tentative conclusions as they go along. Even more than all this, they should be impressed with the fact that the procedure they are following is itself one of great generality, and is typical of what is going on in economics, in government, in social progress—in short, in all phases of life. While I have been teaching inductively for a number of years, it is only recently that I have reached this phase of the process. I now expect my boys and girls to know what induction is, to know when they are using it, and to realize they may and should use it constantly in the classroom and in life outside it. For example, if they are puzzled by the request to express the number of inches in x feet, they should find the number of inches in 2 feet, in 3 feet, in 5 feet, etc., and *should study at the same time*

[2] Orato, P. T.—*The Theory of Identical Elements*, Ohio University Press, Columbus (1928) p. 128.

the method they are using. They may then readily generalize to the number of inches in x feet. The point is that they should constantly fall back upon this inductive procedure, when necessary, is even such a simple problem as this.

Not long ago the eighth grade was studying successive discount. It was not long before the two inevitable questions arose: (1) "Why not add the two rates of discount?" and (2) "Does it make any difference in which order the discounts are figured?" Some textbooks state the facts without giving the pupils the opportunity to investigate. If this is not the case, many teachers with good intentions state the facts for the pupils, who are then satisfied and the lesson proceeds. There is a rare opportunity here for some inductive teaching and learning.

The class began working several examples all three ways. The first problem was as follows: List price, $60; discounts of $33\frac{1}{3}\%$ and 20%. Find the selling price. The pupils readily found that the selling price comes out $32 taking the discounts in either order. Moreover, the result of adding the two rates and taking $53\frac{1}{3}\%$ of $60 is $32. They were ready to conclude then that the problem could be worked in three different ways. This afforded the opportunity to discuss the scientific method. They were familiar with it from their work in science and mathematics. Before making a general conclusion, more examples needed to be studied. Some things had to be held constant, others had to be changed. In this example, the list price and the two rates had been held constant, and the *procedure*—that is, *what had been done with the numbers had been changed.* We now proceeded to *change* the *data* and *repeat the procedure.* At once a different result was obtained. They discovered that changing the order had no effect on the result, but adding the two rates of discount did yield a different result. This prompted study of the previous example to check the tentative conclusion which had been reached—namely, that all three methods were possible. After several moments of study the light began to dawn on the pupils. They realized that when they added the two rates and took $53\frac{1}{3}\%$ of 60 the result was 32, but this was not the *selling price*—it was the *total discount* and the selling price was actually $60–$32 or $28. The *similarity* in *the figures* had led them to an erroneous conclusion. The results showed that this method did not give a satisfactory result in at least two examples Several more examples verified the revised conclusion, and the generalization was complete. But I wish to emphasize that all *through*

this inductive development the pupils were kept conscious of the actual scientific procedure they were following, and that it was a very general one. In this case this was accomplished by frequent references to similar procedures in other connections, such as their work in general science.

A second illustration is afforded by a problem in algebra—the introduction to the laws of exponents. The better textbooks introduce this by means of examples. Thus a short period of preparation reviews the meaning of exponents and proposes the problem. For example, how can $x^3 \cdot x^4$ be written in a *shorter* way? Examples are then provided and the students write out the meaning of the result by use of the definition of an exponent. After a varying number of examples the students reach the generalization that the result is the base raised to a power in which the exponent is the sum of the exponents of the factors. Now an unskilled teacher and many a textbook begins with the rule and proceeds to the examples, thereby robbing the pupil of the opportunity to observe the *meaning* of the process and form his own generalization—the thing he needs most. But please observe again that more than this is necessary. The pupil should be *conscious* of the fact that he is using the *inductive* method. He must be aware that he is seeking for a general result. He must observe that he may change the bases and the exponents at will, but certain elements of the situation must remain constant. Thus it makes no difference whether the problem is $x^3 \cdot x^4$, or $x^7 \cdot x^2$, or $x^5 \cdot x^9$. In each case the *procedure of adding the exponents* is the same. Moreover, by means of examples like $5^2 \cdot 5^4 = 5^6$, it may be driven home that the exponent of the product is applied to the given base. If the pupil once sees that the base is the same in all three powers—that is, that *this element "remains constant"*—he is less apt to write $5^2 \cdot 5^4 = 25^6$, a frequent error which shows lack of the insight which this emphasis on the scientific method will give. At the same time, by means of examples such as $y^3 \cdot y^4 = y^7$, $z^3 \cdot z^4 = z^7$, $a^3 \cdot a^4 = a^7$, he may be led to see that the base may be varied, but again the *procedure* remains the same. One may, if desired, even carry this to the complete abstraction of the form

$$\square^{()} \cdot \square^{()} = \square^{()+()}$$

in order to emphasize these points. Throughout the learning process, however, the student should keep "in the back of his head" the idea that he is seeking the general law *by induction*, and that certain things are changed in order to study the effect

on the result, while others are kept constant in order to keep the problem simple and within bounds. He can readily see that if too many things are changed at once he has too much to observe at one time, and reference to laboratory technique, in which as a rule only one variable is measured at a time, will make the idea clearer.

If these elements of general scientific procedure are kept prominent, we may hope that the student will gain power in generalization. If the student forgets the rule, he has a means at his disposal of getting it back by working it out again. Finally, we may look for transfer to a strange situation because meanings have been stressed and the problem has been taught as part of a general scheme rather than as an isolated fact of the lesson for a particular day. *The course in algebra should be a vehicle for training in generalization and therefore should be taught inductively practically from start to finish.*

AN ELECTRO CHRONOGRAPH FOR LABORATORIES

By John B. Leake
Crane Technical High School, Chicago, Illinois

Many laboratory instructors find difficulty in getting enough stop watches, and in keeping those they have from being carried off. To surmount this difficulty, the author devised an accurate apparatus on the principle of the electric chronograph, which is very rugged and costs about $1.50. This chronograph is shown in the accompanying sketch.

The principal part of this apparatus is an electric clock, which, as is well known, will keep accurate time without losing a second in a year, which is accurage enough for most experimental laboratory work. The model sold in a metal case for use in stores and kitchens seems the most suitable for the purpose, as the dial is larger than on other models of about the same price.

A wooden case is first constructed, and fitted with the single throw switch and binding posts. The wiring is according to the wiring diagram, the wires being placed in grooves in the underside of the base, which are afterwards filled with beeswax.Two of the wires are led up through a hole in the base to be con-

nected later to the terminals of an electromagnet. The base should have four rubber feet on the underside.

The next step is to remove the case from the clock, and also the hands. The clock is then mounted in the top of the case, and its cord run out through the side of the case. A 1" fiber disk is pressed over the spindle of the second hand, after drilling the the disk with a hole slightly smaller than the spindle diameter. The clock dial is next cemented to this disk, using ambroid cement, or rubber cement. Care should be taken to mount the dial so that it is exactly centered over the spindle.

The next step is to mount an electromagnet over the center of the dial. Secure a small one, and drill and tap one end of the

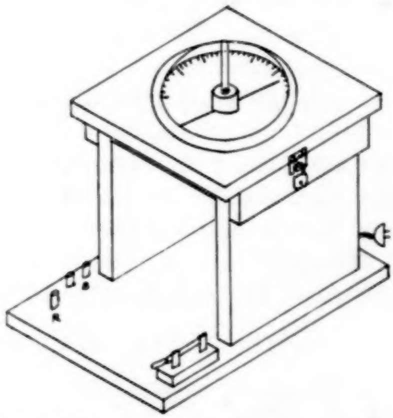

Fig. 1. Electro Chronograph made from an electric clock.

core. In the other end of the core drill a 1/32" hole 1/2" deep. A brass strip supporting arm is now attached to the magnet by a machine screw, the arm attached to the top of the wooden case, and the coil terminals connected with the two wires previously provided. The hole in the lower end of the core should now be exactly over the clock spindle.

Next cut a tin armature 3/8" diameter and solder at its center a brass wire 1/4" long, small enough to slip easily in the hole in the magnet core. Over this armature glue paper to eliminate effect of residual magnetism. Next attach to the armature two light pointers, in line, and long enough so that the end to end length is equal to the diameter of the circle on the clock dial marked in divisions. If desired armature and pointers can be cut in one piece.

The armature is now placed on the dial, with the brass wire

in the magnet core hole, and the arm adjusted so that the armature and pointers will clear the dial when the armature is drawn up to the magnet.

To operate, connect one or two dry cells to the binding posts, plug the clock cord into an A.C. circuit, and start the clock.

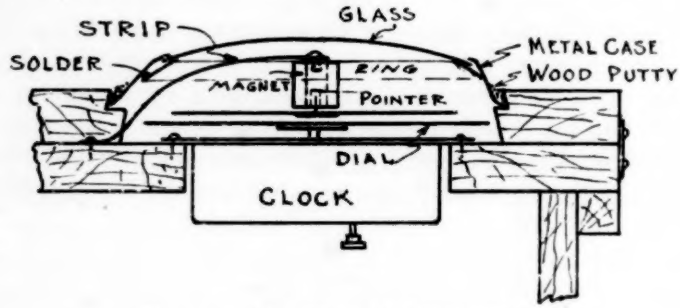

Fig. 2. Section Through Chronograph.

The dial will now rotate. When the switch is closed, the magnet will lift the pointer from the dial. It can be dropped at any desired point on the dial by opening the switch. Timing is accomplished by lifting the pointer at the start of the timing, and dropping it at the close. The movement of the dial records the elapsed time.

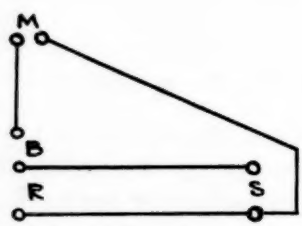

Fig. 3. Wiring Diagram.

This chronometer can be operated at a distance by leaving the switch open, and connecting a switch circuit to the relay posts. To time movements which can pass over contacts, connect a relay to the relay posts, leave the switch open, and wire the contacts to open and close the relay.

To protect this apparatus, it is fitted with a hinged cover and small padlock. The glass clock cover, with its containing metal is fitted into the cover as shown in the section drawing, so that the time may be observed thru the glass.

THE LABORATORY TECHNIQUE IN SECONDARY SCIENCE TEACHING

By Orlie M. Clem
Teachers College, Syracuse University
and
Henry C. Shoudy
North High School, Syracuse, New York

Enlarged aims for secondary education and for the specific field of science instruction are emerging. Is the technique of laboratory instruction in the secondary school keeping pace? Is it possible that a little neglect in this sequestered sector may endanger somewhat our professed general aims? The purpose of the study here reported was to determine current practice and opinion relative to the laboratory phase of high school science teaching. Data were obtained by administering a questionnaire to 250 science teachers in New York State high schools. These teachers were randomly selected, and represent more than half the science teachers of the state. It is believed the study represents a fairly comprehensive statement of current practice for the laboratory technique in secondary schools.

Factor I: Aims of Laboratory Teaching in Science

1. Do you think the laboratory procedure should be to check established laws and reactions? (Yes, 110; no, 111)

The vote on this question indicates an acceptance of tradition and the "new learning" in equal degree. Disciples of the new faith claim the pupil should have some opportunity to explore, to re-discover laws for himself. If, upon leaving the laboratory, the pupil has merely checked some physical laws long established and worn threadbare by generations, science has been for him a rather barren subject. Cureton[1] has likewise found that the majority of teachers consider the chief function of the science laboratory is to provide concrete illustrations for important principles.

2. Do you think the aim of laboratory teaching is primarily to develop a scientific attitude of mind? (Yes, 169; no, 68)

New York State science teachers preponderantly recognize a "scientific attitude of mind" as the primary aim of the laboratory technique in science. It is perplexing how this goal is to

[1] Cureton, Edward E., "Junior High School Science," *School Review*, December 1927.

be attained by the procedure indicated by one-half the teachers under question (1), that is, by checking established laws and reactions. It is doubtful whether the "purpose firm is equal to the deed."

3. Do you encourage inductive thinking on the part of the pupils? (Yes, 235; no, 5)

The mediaeval method of reasoning accepted the general on authority and then proceeded to the particular. Wooster[2] has recently shown that in the scientific method of reasoning, one must proceed from the particular to the general and then from the general to the particular. The data for this question indicate that New York State science teachers have accepted almost unanimously the modern scientific method.

Factor II: Relationship Between Textbook and Laboratory Work

1. Do you teach topics in the textbook at the same time they are being taught in the laboratory? (Yes, 209; no, 35)

The data for this question show that more than 85 per cent of teachers do not divorce textbook work and laboratory work. They are unitary and not disparate phases of the same process.

2. Do you have a class discussion on each topic or unit before introducing it in the laboratory? (Yes, 153; no, 84)

Although the affirmative vote on this question is somewhat less than for question (I), the unitary relationship between textbook work and laboratory work is emphatic.

3. Do you have separate rooms for laboratory and recitation purposes? (Yes, 98; no, 148)

The replies to this question are prophetic of a tendency in secondary science teaching,—to combine the laboratory and the recitation rooms. Influenced by college methods, traditional practice has separated the two rooms on the secondary level.

4. Do you always keep the laboratory periods separate from the recitation periods? (Yes, 131; no, 116)

The even vote on this question indicates a growing tendency to combine the conventional "recitation" period and the laboratory period. The class meeting involves a work period, or a socialized recitation period. Developments in the field of general method as illustrated by project method, supervised study, and socialized recitation, have furthered this new type of period in laboratory work.

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[2] Wooster, Lyman C., "The Scientific Method of Reasoning Versus the Mediaeval Deductive Method," SCHOOL SCIENCE AND MATHEMATICS, December 1923.

Factor III: The Assignment of Laboratory Work

1. Are the directions for the laboratory procedure written? (Yes, 202; no, 36)

In practically 85 per cent of cases the directions for laboratory work are written, that is, either printed or mimeographed. From these data, one wonders whether the problem type of experiment arising from class discussion receives sufficient attention.

2. Is the statement of laboratory work given in problem form? (Yes, 152; no, 82)

The affirmative response indicates that approximately two-thirds of these science teachers present the laboratory assignment in problem form.

3. Are the pupils allowed to choose which problems they shall work? (Yes, 46; no, 189)

In terms of present-day educational theory, the opportunity for pupil choice in only 20 per cent of cases seems regrettable.

4. Are the pupils allowed to suggest problems for laboratory work? (Yes, 149; no, 80)

The affirmative reply to this question indicates more flexibility than is implied in other data of this section.

5. Do you always follow the same procedure in assigning laboratory work? (Yes, 52; no, 191)

If "no pleasure endures unseasoned by variety," and a great teacher like a great submarine commander is "one who is a master of irregularity," it appears that the affirmative vote on this question is too large.

Factor IV: Lecture-Demonstration Versus Assigned Experiments

1. Do you use the lecture-demonstration method in teaching science? (Yes, 210; no, 31)

2. Do you ever perform any experiments for the entire class? (Yes, 230; no, 16)

3. Do you perform demonstration experiments in place of individual pupil performance? (Yes, 149; no, 83)

4. Do you require each pupil to perform every experiment for himself? (Yes, 68; no, 177)

The data for the four questions above indicate conclusively that the lecture-demonstration method has taken a firm hold on secondary science teaching. In general, it is not used exclusively but in conjunction with the individual-experiment

method. Objective experiments thus far reported appear to yield approximately equal results for both methods.

Factor V: Type of Class Period

1. Do you use a double period per week for your laboratory work? (*Yes, 162; no, 81*)

The double period has been the marrow of tradition in laboratory work. It is interesting that one-third of these science teachers now employ the single period. Some of the teachers, no doubt, teach general science exclusively.

Factor VI: Methods of Work in Laboratory

1. Do the pupils work individually while in the laboratory? (*Yes, 99; no, 137*)

Considerably less than half these science teachers have their pupils work individually in the laboratory.

2. If the pupils are paired, are they paired according to their mental ability? (*Yes, 78; no, 108*)

When pairing is used, it is on the basis of mental ability in 40 per cent of cases. This depature from tradition represents no doubt one phase of the general interest in native intelligence and homogeneous grouping.

3. Do all the pupils perform the same experiments? (*Yes, 190; no, 55*)

As indicated earlier, the tendency is in general toward little flexibility of curriculum in the laboratory work; the data on this question indicate some freedom of choice in more than 20 per cent of cases.

4. Do your pupils interpret their own results? (*Yes, 206; no, 20*)

In only a small percentage of cases do teachers report that pupils do not interpret their own results. It would appear that in these few cases the most important aims of science teaching are neglected.

5. Do you require your pupils to make complete conclusions for every experiment? (*Yes, 210; no, 36*)

The present question was asked to determine roughly whether science teachers approve the common catechetical formulae for the conduct and report of experiments. Nearly all teachers insist on complete conclusions for every experiment.

6. Do you require the pupil to give an application to every experiment whenever possible? (*Yes, 188; no, 53*)

The great majority consider application an important step in the scientific method.

Factor VII: Use of Materials

1. Are the materials used as simple as possible? (*Yes, 237; no, 8*)

The *Law of Parsimony* in science holds that of several possible explanations, one should accept the simplest. Recently in secondary science teaching there has been recognized that in general the simplest methods and materials adequate for illustrating fundamental principles, should be used. The science teachers of this study almost unanimously approve the use of the simplest materials possible.

2. Do the pupils prepare the materials for the laboratory work themselves? (*Yes, 127; no, 106*)

More than half the science teachers of this study have the pupils themselves prepare the materials.

Factor VIII: The Laboratory Notebook

1. Do you use prepared notebooks with blank spaces to be filled in by the pupil? (*Yes, 101; no, 136*)

Considerably more than half these teachers have abandoned the traditional laboratory notebook.

2. Do you require your pupils to make complete descriptive notes? (*Yes, 150; no, 90*)

The data of this question as in (I) above, show a tendency to depart from the stilted type of note common to earlier notebooks.

3. Do you require the pupils to write their notes in ink? (*Yes, 206; no, 40*)

It is interesting that 40 of these science teachers do not insist on the formality of ink notes.

4. Do you deduct for poor English or misspelled words in notebook work? (*Yes, 82; no, 163*)

Only one-third of these teachers deduct in grade for English or spelling in notebook work. The data of this entire factor suggest that science teachers have a new conception of the function of the laboratory notebook. Instead of a formal requirement to be judged by its ornament or mechanical exactness, it is becoming a learning aid for developing generalizations in science. The data for the following four questions re-enforce further the same point of view.

5. Do you allow your pupils to make diagrammatic drawings? (*Yes, 237; no, 8*)

6. Do you allow the pupils to use a stencil in making drawings? (*Yes, 127; no, 115*)

7. Do you ever allow the pupils to make their drawings from charts or models, rather than from specimens? (Yes, 167; no, 74)

8. Do you require the pupils to outline their drawings in ink? (Yes, 19; no, 226)

Factor IX: Field Trips

1. Do you take your classes on field trips? (Yes, 136; no, 99)

2. Do you take your classes on excursions to factories and stores? (Yes, 106; no, 122)

3. Do you require the pupils to make a written report of these trips? (Yes, 102; no, 56)

4. Are the visits to these places carefully planned in advance? (Yes, 122; no, 26)

The data for the four questions of this factor indicate that a large majority of these science teachers do not limit their activities to the four walls of an academic classroom. In general, trips are carefully planned, and written reports made.

Factor X: Degree of Specialization

1. Do you use the same methods in teaching first year high or junior high that you do in teaching senior high school pupils? (Yes, 20; no, 198)

Practically all teachers recognize a clear-cut distinction in types of teaching method suitable for the junior and for the senior high school.

2. Do you require pupils to perform minute quantitative work? (Yes, 13; no, 323)

These science teachers are in substantial agreement that minute quantitative work in science has no place in the secondary school.

Factor XI: Use of New-type Tests

1. Do you employ new-type tests in judging the progress of the pupils in their laboratory work? (Yes, 116; no, 128)

SUMMARY

1. The great majority of science teachers agree that "to develop a scientific attitude of mind," is the major aim of laboratory work. Yet half the teachers consider that laboratory procedure should consist in checking established laws.

2. In general, a close relationship exists between the textbook and laboratory work in science.

3. The curriculum for laboratory work is rather inflexible.

The most common practice is for all pupils to do the same experiments from written directions.

4. Both the lecture-demonstration and individual-experiment methods are in general use. They are supplementary rather than mutually exclusive.

5. In general, pupils do not work individually in the laboratory. When pupils are paired, it is usually not on the basis of intelligence. Normally, pupils are required to make complete conclusions, to interpret their own results, and give an application of results for all experiments.

6. In practically all cases as simple materials as possible are used for experiments; pupils prepare materials in more than half the cases.

7. Science teachers now regard the notebook as a valuable teaching instrument rather than as an end in itself. The present notebook is less formal and stilted.

8. Well-planned field trips are commonly used to supplement the work of the classroom.

9. Less than half the teachers make any use of new-type tests in laboratory work.

BIOLOGY DEPARTMENT MEETINGS TO CO-ORDINATE INSTRUCTION AND IMPROVE THE QUALITY OF TEACHING

By A. H. Bryan

Baltimore City College, Baltimore, Md.

Recently, when the local committees on the course of study for minimum requirements in biology met, it was found that there was considerable variation in the subject matter covered and also in the methods of presentation of the important topics.

There is a need for a well defined course of study, closer cooperation and constructive supervision in the subject. Faculty meetings of biology teachers only, instead of the entire Science department, would be productive of more uniform procedures; and, if conducted properly, should be conducive to improvement in both quality and method of instruction besides unifying the subject matter, and coordinating the general aims and objectives of instruction.

The teachers having had no method courses in college confine instruction to didactic methods, laboratory exercises, and questioning. Biology offers many opportunities for putting into practice all of the regular methods used in High School Pedagogy. Practical methods adapt: project and problem, socialized recitation, supervised study, puzzle diagram solution, student reports, illustrated lectures, movies, formal lectures and discussions, debates, through proving questioning, group studies, special topic research in the library, drawing, dissections, trips, collection of specimens, microscopy, laboratory experimentation and problems, written laboratory exercises, theoretical and laboratory achievement and diagnostic tests together with written lessons, all play their part in imparting interesting information and motivating pleasure in the subject. These various methods of teaching the subject are used as the topic demands them to the advantage of the pupil and his growth in the subject.

The first two meetings after preliminary discussion of organization problems should be concerned with methods of presentation of the topics outlined in the course of study. Review the set up of all of these methods and get discussion as to where each method can be used to advantage. This methodology discussion should prove productive of plenty of motivated debate and argument, which would draw out much useful information from the teachers who would have to defend their methods and practices. From the discussion some valuable criteria and data can be pooled for guidance and conduct of all the classes. Teachers who had tried out these methods for the first time might report on them at the second meeting together with their observed results in terms of pupil growth, participation, interest, associations and concomitant learnings.

The third meeting might be confined to coordinating the subject matter of the course of study so that everybody would be teaching approximately the same subject matter, with friendly exchange of special specimens and materials secured by any individual teacher. For example, if I secured some excellent swamp water which showed many interesting algae and protozoa, I would inform the other biology teachers of this swamp water so that we could all benefit by the material sub-cultures collected. Equitable arrangements should be arrived at whereby all the teachers would agree upon time and dates for the use of fixed materials such as: charts, microscopes, hand lenses, slides, etc. so that there would be no friction due to one teacher getting

something that another teacher wanted at the same time, causing confusion and change of lessons plans without fair notice.

The fourth meeting might well be devoted to preparing departmental tests for the first term and then, endeavoring to set up standards of achievement based on the discussed course of study. From this information some objective tests such as those I have had published in SCHOOL SCIENCE AND MATHEMATICS might be given, and diagnostic conclusions drawn pointing out weaknesses in special phases and topics. As an example, my students do best work according to diagnostic achievement tests in botany and human physiology, with lowest achievement results in animal kingdom classification and animal comparative physiology. Why? How can I remedy the situation? What methods do I use? Why don't the topics get across like the other subjects? Perhaps teacher X, gets just the opposite results. Valuable discussion in a faculty meeting of biology teachers will iron out difficulties of this nature in the fifth meeting which would probably take place after the first term results are known.

The biggest problem in democratic institutions is the passed and failed report of various teachers due to the wide range of variabilities. This subject would be fearlessly discussed and conclusions drawn which should act as a guide in solving this difficulty. It would be ironed out in the fifth meeting. The marking systems should be as nearly uniform as possible. Discussion as to what proportion of their final mark should be based upon achievement test, daily recitation and laboratory work is worthwhile. We tentatively adopted the one third plan, which means $\frac{1}{3}$ for daily recitation, $\frac{1}{3}$ for laboratory work and $\frac{1}{3}$ for tests. This simple standardized marking system has its merit in being easily adopted in any Biology department, and satisfying most of the instructors requirements.

The sixth meeting with warm weather in progress and spring in the offing might be devoted to a discussion of field trips, campus tree surveys, and collection of specimens with active student participation. The instructors might devise nature study projects, and then report on how they worked out at the next meeting. Problems connected with coordinating biology with the other departments might be discussed at the next meeting.

The seventh departmental meeting should be the "integrating meeting." In large, school subjects are so completely chopped up, that the mathematics teacher isn't aware of the problems of

the art teacher, etc., yet the art teacher can help the mathematics and biology teachers in graphs and drawings. What can the biology teacher expect from written lessons in composition, oral composition and spelling, rhetoric? If a student asks a question using poor English should a chemistry teacher correct him? The Latin department can cooperate with the biology teacher in Latin derivature scientific nomenclature, how can we foster this desirable relationship? How much chemistry and physics shall we include in our work? To what extent does general science subject matter overlap biology? Any suggestions? Is the history department interested in our development of the biography of great scientists? Will the shops help us build an aquarium and make it a mutual project? Personally I have drawn heavily on the resources of every department in my school, and derived much pleasure and benefit from the contacts, besides orienting myself and the subject with the other activities of the school.

The final meeting would probably be devoted to a review of the years work with frank discussions of methods, results, faults, weaknesses, commendable accomplishments. Bring up specific examples of pupil association and concomitant learning, together with constructive suggestions for improving the quality and teaching techniques. If possible, this meeting should be preceded by a social gathering with refreshments in order to foster the prime motivating factor for professional ethics, professional sympathy, loyalty and cooperation which is "friendship." Friendly cooperation solves most problems in departmentalized teaching. In assuming an authoritative position, a yearly suggestion might be that of inviting all of the departmental teachers to the house for dinner acting in the capacity of host and servant in order to promote friendship , understanding and cordial relationships professionally. Some years ago, I invited the men teachers to a dinner party ending up with a theatre party to see a worthwhile play. That year saw the finest teaching goodwill that I have ever observed anywhere. Such an esprit de corps, is bound to be reflected in increased teaching efficiency because the teacher becomes happy in his work.

Finally, general school supervisory and administrative matters should be presented and explained at any time when required by the principal preferably at the beginning of the meetings.

AN EXPERIMENT WITH POLARIZED LIGHT

By Robert Wilson and William Kunerth
Iowa State College, Ames, Iowa

NEED OF SUCH AN EXPERIMENT

Polarized light is gradually assuming a position of considerable importance, both in scientific and practical fields. Chemists have adopted it as a tool for determining the strength of solutions from the magnitude of the rotations of polarized light. Engineers have taken it up in order to investigate the stresses in structural members by observing the patterns produced by passing polarized light through transparent models under strain. Geologists make use of polarized light to study transparent crystals. Bacteriologists illuminate the fields of high-powered microscopes with it. These are only a few of the many practical applications.

In the scientific field of light, there are quite as many interesting phenomena concerned with polarized light as with ordinary light. The Kerr effect, the Faraday effect, the Zeeman effect, optical rotation, and many others may interest the student of optics. Aside from the practical applications, polarized light is of great importance because it gives the student of optics an aid in grasping the concept of the nature of light—at least the classical concept. In general, experiments dealing with it are lacking in optics laboratory programs. It was with this need in mind that the apparatus here presented was developed.

Interest in a subject is necessary before a real comprehension can be attained. Demonstrations and laboratory experiments are introduced with at least a minor object in view of interesting students in the topics thus presented. All lecturers know that a demonstration which is puzzling interests the onlookers and creates in them a desire to secure an explanation. The quenching of a beam of light by merely reflecting it from two mirrors is just such a demonstration. Since it is concerned with polarized light, it affords a good introduction to the subject.

This apparatus, originally designed by Dr. L. H. Weld of Coe College, Cedar Rapids, Iowa, was redesigned and built here at Iowa State College with a number of improvements of which the most important was the use of the Weston Photronic Cell as an instrument for measuring light intensity.

THE POLARIZING APPARATUS

The principle of the law demonstrated is that the intensity of a beam of light reflected at the angle of maximum polarization from two mirrors varies as the square of the cosine of the angle between the planes of incidence of the mirrors. This is the well-known law of Malus found in every comprehensive textbook on light. The apparatus, as it was designed and built, is

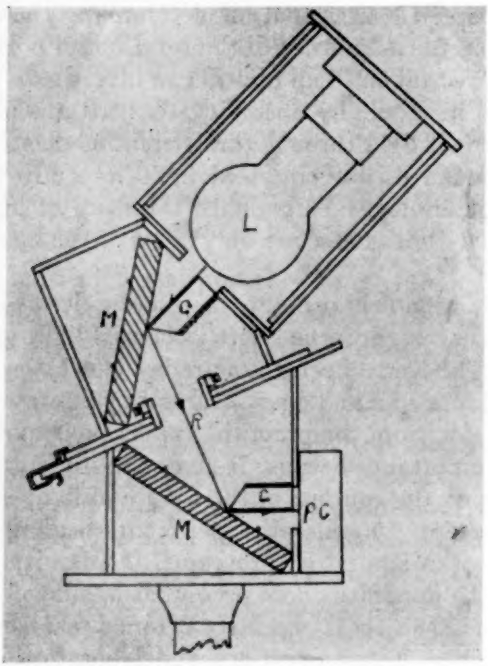

Fig. 1. Schematic diagram of apparatus
L—light source
M—mirror
R—light beam
PC—photronic cell
C—half cylinder

shown in Figure 1. The mirrors, although selected chiefly because of mechanical ruggedness and inexpensiveness, proved to be as nearly perfect polarizers as it is possible to obtain. They are constructed of black plate glass, a centimeter in thickness. Such glass prohibits any possibility of back-surface reflection causing errors. Plain glass, about two millimeters thick painted on the back with a very dull black paint, worked quite well but

was discarded in favor of that mentioned above. The Weston Photronic Cell used to measure the intensity of the light beam was selected because it was very accurate, inexpensive, and easy to operate.

The cell is a so-called barrier-layer cell. It consists of two surfaces; one a good conductor, silver, and the other a poor conductor, selenium, placed in very close contact with each other. The good conductor has approximately 10^7 times as many free electrons as the other. Probably diffusion back and forth across the boundary results in the formation of a cloud of electrons in the selenium just inside the boundary. This is the "barrier-layer." Light passing through the silver and falling on the boundary energizes the electrons which pass from the selenium into the silver. The potential barrier of electrons prevents movement in the other direction. If the external circuit is of low resistance, practically all of these electrons flow on around it. If the external resistance is high, however, there is some leakage back into the selenium. As a result, for low external resistance, the cell current is directly proportional to the light falling on it. The silver surface will be negative so that the amperian current will flow into the silver surface from the *external circuit.* One must use a galvanometer of 100 ohms resistance or lower. For this experiment, a galvanometer sensitivity of about 10^{-7} amperes is required. The ordinary laboratory wall galvanometer is usually quite satisfactory. A 60-watt A lamp furnished the light. As seen in the drawing, the source rotates with the upper mirror about the axis of the beam. The Photronic Cell is attached to the front of the housing by a stout metal clip and contact is made to the cell by means of double-ended binding posts. A rack-and-pinion gear is used to adjust the mirrors.

The apparatus is rather singularly well adapted to the needs of a small physics laboratory. Although that described here was constructed in the College Instrument Shop, anyone reasonably skilled in the use of tools is quite capable of turning out one nearly as accurate. The materials are purposely inexpensive and easily obtainable. On the other hand, of course, if a physics department is fortunate enough to have an instrument maker available, a more handsome and accurate piece of apparatus can be built.

The light source is adjusted so that the filament, leads, etc., are symmetrical with respect to the plane of incidence of the upper mirror. The Photronic Cell is set so that the small disk-

shaped insensitive spot in the center of its sensitive surface is in the center of the beam. This assures that the cell current will be truly representative of the light intensity at all times. The index is designed to clip on so that the zero can be adjusted.

The apparatus proved to be practically fool-proof. The only things that can get out of order, students can easily adjust by themselves. The mechanism of operation is so simple that usu-

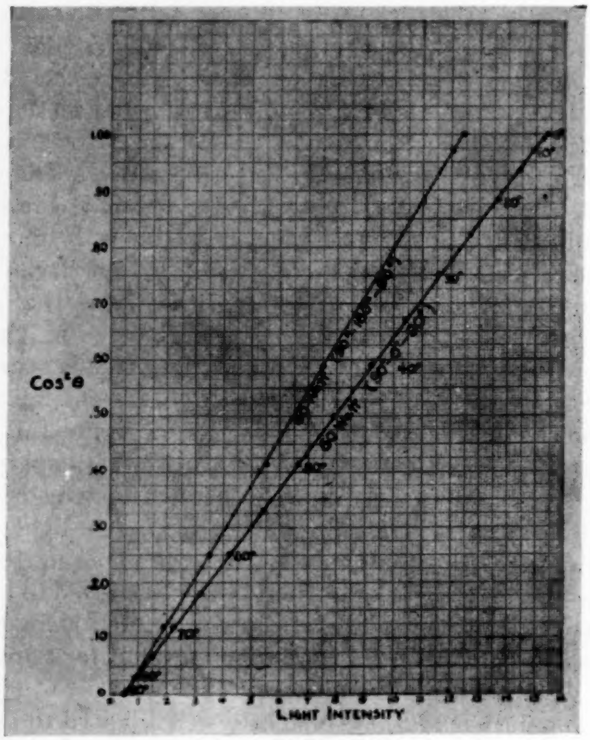

Fig. 2. Curves plotted from data taken with apparatus by student.

ally no explanation is needed. Unlike so many experiments of like nature, the results are always repeatable. They constitute a definite proof to the student that polarized light acts just as he has read that it does.

RESULTS

Students' results with the apparatus are very good. The average experimental error is about two per cent. A student's curve is shown in Figure 2. The galvanometer readings which are pro-

portional to the light intensities are plotted against the cosines squared of the various angles set between the planes of incidence of the mirrors.

The experiment seems to assume a natural place in the usual train of optics experiments. Certainly, it brings out clearly one of the more important characteristics of light. It fills a vacancy usually found in optics laboratories. It is simple, accurate, and easy to comprehend. The authors believe it worthy of a place in either the simplest or the best established optics laboratory for it is well fitted for both.

HOW OLD IS THE EARTH?

By W. T. Skilling
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Impertinent as the question seems Mother Earth has answered it in several different ways. Unfortunately, however, her answers do not all agree. The replies she gave to geologists of a generation ago mentioned a far lower figure than that given physicists today who are persistently raising the same query. Old records have been found but some of them are nearly illegible. Recently an entirely new set of records has been discovered the interpretation of which is giving far more reliable chronological data than has ever before been found. But this data is in the language of a science that was in its infancy at the beginning of this century, and therefore could not have been deciphered at that time.

HOW LONG HAS THE SUN SHONE?

Before taking the earth's evidence in regard to her age suppose we look first to the sun for information. It is customary to go to the parents for the age of their children, and ever since Laplace made his hypothesis of the origin of the Earth we have believed that it was derived from the sun. The fact that Laplace's views have been discredited, and a new theory of the way in which the earth began its independent career has been proposed and accepted does not make it any the less probable that the earth was once a part of the sun.

In 1854 the great scientist, Helmholtz, evolved a theory in regard to the sun's heat that has been almost as long lived and

as universally accepted as Laplace's hypothesis in regard to its origin. Helmholtz assumed that the sun was once as large, at least, as the solar system, and that as it contracted to its present size it necessarily generated heat. Very much as an engineer can compute the amount of energy to be derived from falling water, so Helmholtz computed the amount of energy (or heat) that the material of which the sun is made would produce as it fell in from its ancient position to its present place. Its own force of gravity would draw it in, and heat would be generated in the process.

In this way Helmholtz computed that the sun must have been able to supply its present outflow of heat for the last 25,000,000 years. He estimated that in 10,000,000 years more the sun would have become too dense to shrink much more, and it would cease to be able to give the earth enough heat to support life.

In those days a figure of some 35,000,000 years was considered by geologists ample time for the changes that have taken place on earth. Today geologists are demanding some 2000 million years for the span of life on earth, and a new source of heat has been sought and found in the sun, far more potent and generous than that of the compression theory.

GEOLOGIC RECORDS

Let us next look at some of the records written in the earth which enabled early scientists to reconstruct the story which we now know as geological history. Geology, unlike astronomy, is a comparatively new science. The first geological map was made of England in 1790, (since the time of our Revolutionary War), by William Smith, who was the first to point out the fact that each rock formation has its own peculiar fossils, and that these formations, laid layer upon layer, contain the story of every changing form of life since the world began.

It soon became evident that if we could in some way estimate the rate at which stratified rock was laid down, first, of course, as mud, or, in case of limestone, as tiny shells sinking to the bottom in water, then some sort of estimate could be made of the length of time required for the process.

The next step, after finding rate of deposit would necessarily be finding the depth of the deposit. Since the rocky stratified crust of the earth has been crumpled and later eroded by running water the task of measuring the thickness of strata is not so difficult as at first thought it would seem. In some places

one can walk for miles over the upturned edges of strata, some of which were once thousands of feet below the surface. Professor Holmes of an English University estimates that at least 185,000 feet of stratified rock was laid down during the oldest geologic eras, known as Precambrian time, 194,000 feet in Paleozoic time, 97,000 feet in Mesozoic time, and 75,000 feet in Cenozoic time. This would make a total of 540,000 feet or 105 miles.

Of course this thickness of stratified rock cannot be found in any one place. Different parts of the earth have taken their turn at different times of being below the water, where deposits would be most likely to be made. Then, too, vast tracts would somet'mes be for long periods very little above sea level making erosion slow and deposition correspondingly slow. It is by adding together the maximum deposits of each of the successive periods that the surprising total of 105 miles of layered rock is found. To find the length of time required for this deposit to form, present rates of deposit in different parts of the world are studied.

Our approach to this problem is to learn the rate at which the rivers of the world are now carrying sediment into the sea. Anyone who has ever seen the Missouri River, or the Mississippi below the point where the muddy Missouri empties into it, can readily appreciate the eroding and carrying power of water. Above the mouth of the Missouri where the Mississippi comes from low lying country the water is clear. But water that has rushed down from the great western plateau region and out of the narrow gorges of the Rocky Mountains is abundantly supplied with material for building up deposits on the bottom of the Gulf of Mexico. Computation shows that the carrying power of running water varies as the sixth power of its velocity.

Estimating the average volume and rate of flow of the Mississippi River, and the load carried by it, it is found that enough material is annually emptied into the Gulf to form a block of earth a mile square and 250 feet high. Such estimates as these form the basis for this line of reasoning that finally leads to a conclusion as to the age of the earth. But one can readily see how uncertain is the whole method because of the evident impossibility of either getting the exact rate of present deposition or of being sure that this has always been the rate.

Another most important fact to be considered before we conclude that the age of the earth is equal to the time required

to deposit the strata now known to exist is that there have evidently been long intervals of time between geological eras when no deposits were being made, at least not where they are now accessible. These were periods of erosion but not of deposit upon regions now above water where examination is possible. The ancient mountains of Canada, the oldest on the North American continent, were worn down to a low peneplane during an interval that occurred at the end of the Archeozoic Era, the oldest Era of geologic history.

Such missing periods of unknown duration in the continuity of our record obviously make the resulting chronology too short. The age found by measurement of strata is evidently only a minimum figure.

For another gauge of time scientists have gone to the sea, rather than to the land. The ocean doubtless began to be formed as soon as the earth became cool enough to allow rain to fall and remain on its surface. At first the gradually accumulating water would have been as fresh as rainwater impounded behind a dam in one of our great reservoirs. The salt is a gradual accumulation due to the fact that salt is slowly leached out of the ground and carried to the sea, and that in evaporation of water containing it the salt is left behind.

The presence of salt in well water or in any water that has seeped through the ground is easily detected by adding to the water a few drops of silver nitrate, when a cloudy, white precipitate of sodium chloride forms. The chemist can determine the amount of salt in river water which empties into the sea, and then as in the case of suspended sediment, the total amount of salt annually finding its way to the ocean can be estimated. The amount so found is surprisingly large. Thirty-five million tons of sodium, one of the constituents of salt, is annually added to make sea water more salty.

Since the smount of mineral matter in sea water is known to be about $3\frac{1}{2}$ pounds to the hundred pounds of water, the total amount of salt or of sodium in the ocean is calculable. All that remains to be done is to find how long it would take this known amount of salt to accumulate at the known annual rate of increase. The chief element of uncertainty in this method as in the sedimentation method lies in the fact that in the past the rate of salt formation and transfer to the sea may have been different from the present rate.

At the beginning of the present century geologists gen-

erally regarded one hundred million years as being the probable age of the earth, whether measured by the thickness of stratified rock or by the amount of salt in the sea. Today the results of these methods are interpreted to indicate an age of some 300 million years.

THE URANIUM CLOCK

In 1927 a committee of scientists appointed by the National Research Council began an investigation of this problem that had defied accurate solution by geologists. These men attacked the question from a new angle. The clocks by which geologists had sought to time events had run irregularly or not at all. One of the most surprising discoveries of our century has been a clock that runs without variation for millions of years. Minerals that contain the element uranium have been found to contain lead also. And it is now known that the lead is a product of the uranium. Gradually through thousands and millions of years uranium, whose atoms are the heaviest of all substances, disintegrates, changing first into one thing, then this into another, and so on until it becomes lead.

This gradual change, known as radioactivity, proceeds at a perfectly constant rate, never faster and never slower, regardless of changes in temperature or any other condition. Moreover the rate at which the changes take place can be measured, so that the age of any uranium mineral can be found by simply analyzing it to find what percentage of the uranium has become lead. One per cent changes to lead in about 70 million years.

The radioactive element thorium also changes in course of time to lead, so thorium like uranium has, through the ages, been ticking off geologic time as atom after atom changes from its original state into lead.

Both uranium and thorium give off the gas helium, atom by atom, at a measurable rate, and if this gas becomes occluded in the rock where it is formed, it, like lead, measures time. Being a gas, helium is liable to escape, and so is less reliable than lead as an index of time.

Many radioactive minerals from various parts of the world have been analyzed to find their relative contents of uranium or thorium and lead. Of course different samples will vary widely in the age they indicate, but this is because they come from newer or more ancient geological formations. Those from rocks of the comparatively recent Oligocene period show an age

of 37 million years; those from the earlier Permian period 204 million; from the late Precambrian 587 million; and from the lower Precambrian period 1257 million years. The oldest rock in the world so far found, was in Russia. It indicated the yet more unimmaginable age of 1852 million years. And it was an intrusive rock, surrounded by an obviously older formation.

Thus science has examined record after record in an attempt to date the world's beginning, and has at last arrived at an estimate that places the time at about 2000 million years ago. This represents the span of geologic history since the first rocks were formed. Cosmic history, reaching on back from the time the earth became cool enough to harden into rock, clear to the time when the material of which it is composed was drawn out of the sun and started on its course, is still a very uncertain interval. And this theory as to how the earth and its sister planets came out of the sun is another story.

VOICES OF SCIENTISTS RECORDED FOR FUTURE CORNELL STUDENTS

Inaugurating a plan to preserve for future generations on the campus the voices of distinguished persons connected with Cornell University, short addresses by Dr. William L. Bragg and Sir Arthur Stanley Eddington have just been recorded. The plan will result in a library of records which will eventually have historical significance, and Prof. Vladimir Karapetoff of the Cornell School of Electrical Engineering has volunteered to make the records on his high-fidelity voice-recording equipment perfected after several years of experimenting.

Dr. Bragg, professor of physics at Manchester (England) University and lecturer this term at Cornell, outlined the work which led to his receiving the Nobel Prize. Sir Arthur Eddington, the British astronomer lecturing at Cornell, read a passage from one of his books.—*Science Service.*

TWO PROTEIN BUILDERS SHOWN NECESSARY FOR HUMAN LIFE

Discovery of two substances essential for life and growth were reported by Dr. William C. Rose and Madelyn Womack of the University of Illinois at the meeting of the American Institute of Nutrition. This newly organized scientific body recently held its first annual meeting.

The two substances described by Dr. Rose are leucine and isoleucine. They belong to the chemical family of amino acids, which have been called building blocks of the protein substances in our food. There are eighteen or twenty of these amino acids. Previously four of them had been found to be indispensable food elements—indispensable because the body can not make them itself. Now the Illinois investigators have found that two more of these amino acids are indispensable. The discovery was hailed by fellow scientists as an outstanding contribution to knowledge of nutrition.

CONCRETE INTERPRETATIONS OF DIRECTED NUMBERS

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A. INTRODUCTION

It is the belief of the author, based not only upon his own teaching experience but upon the experiences of others, that the greatest values of algebra lie unobserved if it is taught in a mechanistic way. The greatest success in the teaching of algebra can be obtained by giving to its symbols and laws concrete interpretations. An article by the writer, "The Presentation of Positive and Negative Numbers," in School Science and Mathematics, for January, 1911, was an exposition of the use of a few concrete illustrations in teaching that unit. The continual employment of this method since then has led to some improvements in its techniques and to its applications in a broader field. The purpose of this article is to point out these new techniques and applications. The specific objectives are: first, to describe some concrete illustrations of directed numbers, both real and imaginary; second, to explain some concrete, interpretations of the use of directed numbers in the fundamental processes; and third, to outline a method of teaching directed numbers which has been employed successfully.

B. REAL NUMBERS

1. Illustrations.—The use of the thermometer to motivate the teaching of signed numbers is now so common as to need no explanation here. Other concrete illustrations of signed numbers which are frequently used have been assembled in the table on the following page. Each illustration extends horizontally across the page, and consists of a description of what constitutes the negative number, the zero point, and the positive number.

Of these illustrations, attention is called especially to the last two, the seating of pupils in the school room, as this illustration will be referred to frequently.

To show that positive and negative numbers are in daily use by the public, the teacher needs only to refer to the financial pages of the daily paper, or in winter time to the daily weather reports.

Negative Number.	*Zero Point.*	*Positive Number.*
Pupil's home, ten houses west of the school.	School building.	Pupil's home, two houses east.
Wilson Lake, two miles south of the school.	School building.	Beaver Falls, six miles north.
A town, ten miles northwest.	Town in which the school is located.	A town, thirty miles southeast.
Depth of water in a lake, forty feet.	Surface of lake.	Height of hill, eighty feet above the lake surface.
Tip of root of a tree, four feet down.	Ground level.	Top of tree, twenty feet up.
Submarine, submerged fifty feet.	Sea level.	Hydroplane, twelve hundred feet up.
Five days ago.	To-day.	Day after to-morrow.
9 A.M., counted as three hours before noon.	Noon.	2 P.M.
Underweight, eight lbs. less than normal.	Normal weight.	Overweight, three pounds.
Factory production for week, 100 pairs of shoes below normal.	Normal output.	Production, 300 pairs of shoes above normal.
Sale at a loss of fifty dollars.	Purchase price.	Sale at a gain of nine dollars.
A debt of twelve dollars.	No money and no debts.	Cash on hand, ten dollars.
Decrease in value of stock, $\$\frac{1}{4}$.	Closing quotation of stock.	Increase of $\$\frac{1}{2}$ in value of stock.
Three strokes in golf worse than par.	Par strokes for the course.	Five strokes better than par.
Pupil sitting two seats to the left of the middle seat.	Pupil sitting at the middle of the row.	Pupil sitting four seats to the right.
Pupil sitting three seats back of the pupil chosen as zero.	Any pupil.	Pupil sitting one seat in front of the zero pupil.

The concrete illustrations of signed numbers should establish these facts. Zero may be interpreted as a point on a scale. Positive numbers are by custom usually counted toward the right or upward, but may be counted in any direction. Negative numbers are merely numbers counted in the opposite direction from the positive numbers.

Students enjoy studying these concrete illustrations and discovering examples of their own. By emphasizing these interpretations, algebra becomes a vivid subject, rich in real meanings, and easy to teach.

2. *Addition.*—One way to teach the meaning of algebraic addition is to dramatize it. A pupil near the middle of the front row may be chosen to represent zero. The first, second, and third pupils at his right represent plus one, two, and three,

respectively. They tell what they represent. In a similar way, the pupils at the left of zero take the parts of minus one, minus two, minus three, and so on. Any pupil in the room may be asked to start from the seat of the pupil who is plus one, walk toward the right two seats, and tell the number of the pupil where he stops, plus three. The numbers corresponding to this activity are written on the board, and the result, which was obtained by the pupils from their own observation, is written before any rule is stated. In the same way, a pupil starts from seat minus two, advances one seat, and tells where he stops. It is pointed out in both examples that because he is advancing he is going in a positive direction. Several illustrations of this type are used.

Then a pupil is asked to start at seat plus three and walk one seat toward the left. It is made clear that he is now traveling in a minus direction, but as before he has a starting point, is told how far to go, and which way. In each example he finds his goal or destination. The numbers used in each illustration, and the results obtained by the pupils from their own experiences are written on the board. They are convinced from their activities and observations that these results are true. They are told that all these examples illustrate algebraic addition. In this type, algebraic addition means starting at a known point, traveling a known distance, and finding the goal. The starting point may be positive or negative. The direction of travel may be the same.

It is explained that the name given to a number without regard to sign is its absolute value. This is illustrated concretely by showing that the actual distance traveled is just the same whether the pupil goes to the right three seats or to the left three seats. The sign of the number that is added tells the direction of travel.

Referring to the large number of examples now on the board, the teacher may now, and not before this time, ask the challenging question, "Is there a shorter method of finding these results than by counting? Who will discover the shorter method?"

The teacher then calls the attention of the class to the examples which have the same signs in the addends, and asks what might be done to the absolute values to obtain the answers in these examples. The answer is obvious, it is before the pupils, they know it is correct from their own concrete demonstrations,

and without hesitation they state the rule themselves. Similarly, when their attention is called to the examples in which the signs are different, they become rediscoverers of that rule also.

Of course the familiar diagram of the number scale should not be neglected, as its use is very helpful, and it correlates very closely with the dramatization.

Concrete illustrations of algebraic addition are by no means limited to traveling back and forth in a school room. Other typical problems are included in the following table which is self explanatory.

Original Value.	Change in Value.	New Value.
Temperature, −17 at 7 A.M.	Rises 25 degrees.	What is the temperature at noon? $(-17)+(+25)=+8$
A man has $350.	He incurs a debt of $475.	Find his balance. $(+350)+(-475)=-125$
Top of ground, 80 feet above sea level.	Depth dug to reach bed rock, 130 feet.	How far is bed rock below sea level? $(+80)+(-130)=-50$
Score in a card game called "63," 12 in the hole.	Player gets set 45 points.	What is his new score? $(-12)+(-45)=-57$
Fire damage, to house, $500.	Loss of furniture, $300.	Find total loss. $(-500)+(-300)=-800$
Original value of house, $2400.	Damage by fire, $500.	Estimate present value. $(+2400)+(-500)=+1900$
Elevator on 11th floor.	Ascends 5 floors.	What floor does it reach? $(+11)+(+5)=+16$
Construction began three years ago.	Estimated time for completion of contract, 8 yrs.	When should work be done? $(-3)+(+8)=+5$

In order to include all types of problems, algebraic addition may be given this interpretation. Algebraic addition is starting with a known value, combining with it a change in value, and finding the new value. Traveling ahead, gains, profits, and the like are illustrations of the addition of positive numbers. Traveling backward, losses, defeats, and the like are illustrations of adding negative numbers.

3. Subtraction.—Algebraic subtraction may be dramatized in a similar manner. However, it is emphasized at the very first that algebraic subtraction like subtraction in arithmetic is finding the difference between two numbers. Two pupils, representing different numbers are asked to stand. One of them is designated as the first pupil, the other as the second. Then another pupil is asked to walk from the first to the second one,

tell how far he walked, and which way. For instance, how far is it and which way from the pupil at seat minus two, to the pupil at seat minus five. A few examples illustrating every possible combination of signs are used, and in every example the number which represents the starting point is written as the lower number or the subtrahend, the number which represents the stopping point is written as the upper number or the minuend, and the answer with the correct sign is written before any rule is heard. The pupil sees on the board the signed answer which corresponds exactly with what he sees his classmates doing. He is convinced that these answers are correct because they agree with his personal experiences. For instance, the pupil knows that the answer to the example given above is minus three, not from any rule, but because he has seen a pupil walk a distance of three seats in a negative direction, from seat minus two to seat minus five.

After enough illustrations have been placed upon the board, the teacher may ask this challenging question, "Could we obtain these results in a shorter way than by counting? Could we obtain the same results by changing the sign of the lower number mentally and proceeding as in addition? Let us test each example and see."

As a result of this suggestion and test, the pupils find that the rule gives the same results as their concrete experiences, and are convinced that it is correct.

Typical problems illustrating algebraic subtraction are easy to find. In algebraic subtraction, the original and the new value are known, and the change in value is found. This may be interpreted as finding the difference in position of two points on the scale. To make this even clearer a diagram of the scale may be drawn. The first or original value is the starting point, and it is also the subtrahend. The new or the last value is the stopping point and this is the minuend. The motion is from the point representing the start or the subtrahend toward the point representing the goal or the minuend. A positive remainder indicates that the direction of travel is positive. A negative remainder indicates it is in a negative direction. The first number that is mentioned in a problem is often not the earliest or the original value. The conditions of the problem, not the order of naming the numbers, determines which is the subtrahend and which is the minuend.

One problem in subtraction is explained in detail here to

show how clearly this interpretation fits the real situation. John lives six blocks east of the schoolhouse, and Peter lives twelve blocks west of it. How many blocks is it from John's house to Peter's house? Since we start from John's house, plus six is the subtrahend. Since we stop at Peter's house, minus twelve is the minuend. Changing the sign of the subtrahend and proceeding as in addition, minus eighteen is the answer. This result shows that it is eighteen blocks from John's house to Peter's house, and we travel west. Now the reverse problem may be considered. How far is it from Peter's house to John's house? Now, minus twelve is the subtrahend, plus six is the minuend, and we find the answer to be plus eighteen. This means that it is eighteen blocks from Peter's house to John's house, but this time we travel east. The actual distance traveled is the same in each example, and this corresponds to the absolute value of the remainder. The sign of the answer shows the direction traveled.

In order to state a problem in subtraction correctly, it is necessary to state two known values, and to tell which way the difference between them is to be found. For instance, this problem might be given. The roots of a tree grow down into the ground 25 feet and the tree is 42 feet high. It is not sufficient to ask what is the difference between these points. It is necessary to ask specifically, either, how far is it from the lowest root to the top of the tree, or, how far is it from the top of the tree to the lowest root.

Subtrahend.	*Minuend.*	*Difference.*
An ariplane is up 1250 feet.	A few minutes later its height is 700 feet.	How much did it go down? $(+700)-(+1250)=-550$
Philip has won 15 points in a game.	James has lost 12 points.	How many points is James behind Philip? $(-12)-(+15)=-27$
Mary has lost 42 points in a game.	Katherine has won 23 points.	How many points is Katherine ahead? $(+23)-(-42)=+65$
Joseph descends 400 feet from a mountain camp.	Morris descends 1200 feet from the same camp.	How far below Joseph is Morris? $(-1200)-(-400)=-800$
Henry received $35.	After buying some clothing, he had $11 left.	How much did he spend? $(+11)-(+35)=-24$
Roadsign west of Buffalo reading Buffalo 40 mi.	Roadsign west of Buffalo reading Buffalo 10 mi.	How far did Mr. Evans drive toward Buffalo? $(-10)-(-40)=+30$ Did he drive east or west?
Esther is 18 years old.	Once she was 4 years old.	How long ago was that? $(+4)-(+18)=-14$

In the above table are problems of different types illustrating algebraic subtraction stated more briefly than the preceding ones. In every problem, the starting point or subtrahend is placed at the left, the goal or minuend is given next, and the difference or change in value is placed at the right.

4. Multiplication.—The following problems illustrate the multiplication of signed numbers, and the manner in which the real meaning of this process may be taught.

A man went to work for $6 a day. From his point of view this is a positive number because it is what he is earning. If he has worked four days, the question may be asked, how much has he earned since he began work. Time since an activity began is positive. The solution is: $(+4)\ (+6) = +24$. Before any rule is stated, the pupils know that the result is positive because it is the amount he has earned.

Suppose another man is out of work. The cost of his room and board is two dollars a day. Of course this is an expense to him and is negative. If he has been out of work ten days, he may wish to know how greatly he has fallen behind financially since his unemployment began. As before the time is positive. The solution is: $(+10)\ (-2) = -20$. Again, before any rule is given, the pupils can see the reality and necessity for the minus sign in the answer because it represents a decrease in his cash.

About this same man, another question might be asked. How much better off was he, ten days ago? Now time ago is negative. Hence the solution now is: $(-10)\ (-2) = +20$. The pupils see that this result is positive because he had more money at the time he lost his job than he has now.

Suppose that for three hours, an airplane from Washington, D. C., has been traveling south at an average speed of 85 miles an hour. How far is it from Washington? Obviously, this is the solution: $(+3)\ (-85) = -255$.

A tank is being filled at the rate of 25 gallons a minute. This rate is positive. Five minutes ago, of course the tank was less full than it is now. Buy by how much? $(-5)\ (+25) = -125$. The negative sign of the answer agrees with the facts.

After many examples showing all possible combinations of signs have been placed on the board and tried by the pupils at their seats, then, and not until then, the attention of the pupils may be called to the relation between the signs. When asked to tell what they observe, they will give the rule of signs themselves. Better still, they are convinced of its truth.

The same conclusion may be arrived at by considering each multiplication as a series of additions of the same number, starting from zero. The following examples illustrate this procedure:

$(0)+(+3)=+3$; adding one $+3$, $(+1)(+3)=+3$.
$(0)+(+3)+(+3)=+6$; adding two $+3$'s, $(+2)(+3)=+6$.
$(0)+(-3)=-3$; adding one -3, $(+1)(-3)=-3$.
$(0)+(-3)+(-3)=-6$; adding two -3's, $(+2)(-3)=-6$.
$(0)-(+3)=-3$; subtracting one $+3$, $(-1)(+3)=-3$.
$(0)-(+3)-(+3)=-6$; subtracting two $+3$'s, $(-2)(+3)=-6$.
$(0)-(-3)=+3$; subtracting one -3, $(-1)(-3)=+3$.
$(0)-(-3)-(-3)=+6$; subtracting two -3's, $(-2)(-3)=+6$.

The results are first shown to be true from the laws of addition and subtraction previously established. Then, when the results are considered as products, the laws of signs may be stated by the pupils from their own observations.

5. *An Interesting Experiment.*—To establish the reality of positive and negative products in still a different way, the following experiment may be tried. Keeping in mind the same conventions that we have used before in regard to signs, namely, that distances measured toward the north and east are plus while distances measured toward the south and west are minus, if you stand at the south-west corner of a rectangular schoolroom, its dimensions are both plus relative to you, and its area is positive. Now, walk over to the south-east corner. As you stand there, the side measured from you toward the west is minus, the one toward the north is plus, and the area of the room relative to you is now negative. Yet it is the same room as before. Its area, now negative, is just as real as when you were at the south-west corner. Similarly, at the north-east corner, the area, being the product of two negative directions, is again positive. Finally, at the north-west corner, the area is negative again. The absolute value of the area, that is, the area without regard to sign, does not change. The sign of the area depends upon the extension of the rectangle relative to the different corners.

The same conclusion is reached by starting at the lower left hand corner of a section of blackboard or a sheet of paper. Placing the finger upon the lower left hand corner, it may be seen that the dimensions are both plus and the area also. Passing around the rectangle, in the same way as before, exactly the same results are obtained.

6. Division.—The most direct way to teach the rule of signs in division is to consider the process as the inverse of multiplication. Then call to mind the fundamental relation that the dividend equals the divisor times the quotient, which is true from the definitions of the terms. Next assume that this relation holds true when the signs are included with the numbers. Finally questions like the following may be asked. What signed number multiplied by $+3$ makes $+15$? Ans. $+5$. What signed number multiplied by -3 makes $+15$? Ans. -5. What signed number multiplied by -3 makes -15? Ans. $+5$. What signed number multiplied by $+3$ makes -15? Ans. -5. The pupils should work several examples like these on the board and on paper using the fraction as the symbol of division and always including the sign, thus: $+15/-3=-5$. From their own observations, the pupils will give the rule of signs themselves.

However, all these steps are made more clear and our assumption is seen to be justified if we supplement our procedure by the use of some concrete examples.

Mr. Peterson in his will gives $5000 to be divided equally among his five children. How much does he give to each? $(-5000)/(+5)=-1000$.

Marcella finds that she has saved $18 since she began working in the store. If she has been employed 9 weeks, how much has she saved each week. Both these numbers are positive, and the fact that the answer is positive checks with the fact that it consists of savings.

An aviator left an airport 600 miles behind him 5 hours ago. Find his average speed. Distance backward is negative. Time ago is negative. The solution is: $(-600)/(-5)=+120$. Of course, the positive answer corresponds to the fact that he is flying ahead.

Another airport is 420 miles ahead of this aviator. What must be his average speed in order to reach it in 3 hours. Distance ahead and time ahead are both plus. The answer and its interpretation are obvious.

How long will it take to sink a shaft in a mine to a depth of 300 feet at the average rate of 15 feet a day? Both numbers are negative, and the result which is positive shows that the time when the shaft will be finished will be in the future, which of course seems reasonable.

Division by a negative number often requires very careful analysis before the result can be correctly interpreted. A man

began walking north 6 hours ago. He is now 18 miles north of his starting point. What is his rate? Dividing $+18$ by -6 gives a negative rate, but the rate is north and hence positive. This means that whenever simple rate is to be found, the time must be considered as elapsed or positive time. Then, in spite of the way this problem is worded, it must be solved thus: $(+18)/(+6)=+3$. Using negative time, we have $(+18)/(-6)=-3$. This may be interpreted as meaning that at the beginning of each hour he was 3 miles south of his location at the end of the hour.

Using the rectangle, however, it is easy to find a simple illustration of the division of a positive number by a negative one. Here is one. The area of a room is plus 780 sq. ft. One dimension is minus 30 ft. What is the other dimension? In which directions do these dimensions extend? From which corner are they measured?

In all these fundamental processes, the pupil from his own experiences by the use of concrete illustrations and interpretations has become convinced of the truth and consistency of all our assumptions and procedures. He has stated the rules as a result of his own observations and with the joy that goes with discovery. Knowledge acquired in this way has fixed associations at the very beginning; and through drill, its application easily becomes a matter of automatic control.

C. COMPLEX NUMBERS

No attempt can be made within the limits of this article to enter into a technical treatment of the representation of complex numbers. Some simple concrete illustrations of complex numbers have been used effectively in my classes, and these will be described. All these illustrations are based upon this reasoning.

If we take a line one inch long and place it in a positive position, say, pointing to the right from the origin, and then rotate it about the origin through 180 degrees, we have multiplied it by -1. If we rotate it 180 degrees more, we bring it back to its original position where it again represents $+1$. Two multiplications by -1 produce $+1$, by the law of signs. Two rotations of a line through 180 degrees produce $+1$, by this experiment. The position of the line when rotated half way from $+1$ to $+1$ represents one of the equal factors of $+1$, namely -1. Now, the multiplication of $\sqrt{-1}\ \sqrt{-1}=-1$, by definition. Then, the

position of the line when rotated half way from $+1$ to -1 represents one of the two equal factors of -1, namely $\sqrt{-1}$. Therefore, the imaginary unit $\sqrt{-1}$ is a line extending from the origin at right angles to the line which represents $+1$. We may adopt the convention that positive imaginary units may be counted at right angles up from the axis on which the real units are counted, and that negative imaginary units may be counted downward at right angles to this real axis. But this makes imaginary numbers just as real as real numbers. They are.

Let us take the illustration formed by pupils as they are seated in class which we referred to at the first of this article. Let us choose one row of seats near the center as the real axis, and some pupil will be glad to volunteer to act the part of zero or the origin. Then the aisle in which that pupil is sitting becomes the imaginary axis. A pupil in this aisle two seats in front of the origin represents $+2\sqrt{-1}$, a pupil in this aisle three seats back represents $-3\sqrt{-1}$. To bring out the distinction between the real and imaginary numbers, the real number -4, for instance, may be represented by a pupil on the real axis or row.

It should be noted that numbers are real or imaginary in relation to their direction from the origin, real numbers being counted on some axis arbitrarily chosen, and imaginary numbers on an axis through the same origin perpendicular to the real axis. We found that negative quantities were counted in the opposite direction from positive ones. We now find that imaginary quantities are counted at right angles to real ones.

Complex numbers are those which consist of a real part and an imaginary part, often represented by the symbols $a+bi$. Can complex numbers be represented concretely? Again let us use our class.

Consider the number $3+2i$. We count three aisles to the right of the pupil acting as origin and then two seats ahead. The pupil at that seat is asked to rise. He does so, surprised and delighted to find that a complex number can actually be represented by a real person in a real place. Similarly, consider the number $-1-3i$. We count one aisle to the left and backward three seats.

Every complex number may be illustrated in this way, that is, by using two mutually perpendicular distances measured first to the left or right from the origin and then up or down. It

should be noted that this method avoids the error of thinking of a complex number as the length of a line.

Of course to supplement the dramatization, and for purposes of drill, squared paper should be used. By their own activities, the pupils have made the use of squared paper meaningful.

Concrete examples of complex numbers may be found outside of the school room. A few of these will be described.

If any square of a checker board that is near the center be chosen for the origin, every square on the board represents a complex number except the row of squares from left to right which contains the origin, those numbers being real. This illustration may be used as a basis of explaining that that all numbers may be considered as complex, real ones being the special group formed when in the general symbol $a+bi$, the coefficient b becomes zero.

In order to reach his home from the post office, Mr. Johnson travels easterly on a road for 3 miles and then on another road north for 2 miles. Relative to the post office, his home is located at the complex number $3+2i$.

A kite is flying at a height of 125 feet above the ground over a point 300 feet south of the boy who is holding the string. The position of the kite relative to the boy is represented by $-300 +125i$.

On the wall 14 feet in front of my desk and 7 feet above the level of the top is a picture. Relative to the top of the desk, this picture is in the position $14+7i$. On the baseboard of the wall 5 feet behind me and $2\frac{1}{2}$ feet below the desk top is the wall socket where the cord of my study lamp is attached. This outlet is in the position $-5-2\frac{1}{2}i$.

From the top of a mountain, a lake is seen 1200 feet below and 500 feet north of the peak. Considering the downward distance the imaginary component, the position of this lake relative to the peak is the complex number, $+500-1200i$.

Before interpreting the uses of complex numbers in the fundamental processes, it is necessary to study the technical diagrams which may be found in all standard textbooks covering this subject. The explanation of these figures need not be repeated here. In fact, for this part of the unit, their use affords the clearest and simplest explanation of what is meant by the fundamental processes with complex numbers. The dramatic representation of the complex numbers should however precede the study of the diagrams.

D. CONCLUSION

Every directed number whether real or complex may be represented concretely. The use of these concrete illustrations motivates the unit, promotes understandings, and makes it easier for the pupils to acquire skills in computation with directed numbers. Moreover, by the use of this method, the study and the teaching of this unit becomes enjoyable; pupils are led to have a greater appreciation of the wonderful order that prevails throughout the universe, and the mathematical system that binds together all its intricate parts.

THE DENSITY BALL

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In the study of density and floatation, it is helpful to be able to demonstrate that "floating" is a relative term and that it concerns itself with the densities of the different substances under consideration. For example, a piece of coal which is generally accepted as being a *sinking* body, as far as water is concerned, becomes a *floating* body when placed in a solution of zinc sulfate or zinc chloride. This demonstrates this property in a manner different from the traditional floating of nails or lead shot on mercury, and suggests a field for experimentation for wide-awake students that is stimulating, instructive and conducive to mental growth.

In this same connection, the "density ball" can be used and with it can be demonstrated (1) the "relativity" of floatation and (2) the variation of the density of water with change in temperature.

A home-made density ball can be made in two ways. Obtain a small glass jar such as is used for mayonnaise or cheese. It should have an air-tight cover. Put a small amount of water into the jar and close the cover tightly. Place it in a battery jar of water and note whether it floats or sinks. If it floats, keep adding small quantities of water until the jar just submerges. By varying the amount of water in this manner, it is possible to adjust it so that the jar will sink in warm and float in cold water.

Another way to make a density ball is to use a wooden weighted cylinder such as is employed in the experiment of the Law of Floatation. Wind 6 or 8 turns of fine, bare copper wire on the stem of a thumb-tack and insert the latter in the lower end of the wooden cylinder. As the latter by construction has a density nearly equal to that of water, it is a farily easy matter to obtain the proper density for warm and cold water by cutting small pieces of wire off the thumb-tack. To avoid absorption of water by the cylinder, it should have a coating of paraffin. Then, once adjusted, it can be used whenever occasion arises.

Sometimes the regular brass density ball becomes slightly dented due to careless handling or dropping. This renders it useless for the purpose of this demonstration. This can be overcome by placing the ball in a dish of molten paraffin and giving it several coats of paraffin depending on the size of the dent. By trying it in a jar or water after each coat, a point will be found where it will function as well as when it was new.

CURRICULUM REVISION TO MEET THE NEEDS OF HIGH SCHOOL PUPILS*

By A. W. Hurd
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One of the outstanding conclusions stated in a study[1] made recently was that "an overwhelming majority of writers, who suggest inadequacies in the teaching of high school science, agree that the greatest need is a reorganization of content or subject matter to meet the needs of the pupils enrolled." Probably no one will dispute this assertion, but the usual manner of justifying present curricular practices is to insist that they are the results of evolutionary development and if pupils will only apply themselves and learn the lessons assigned to them, there will be no cause for criticism. The physics teacher says, "Why, anyone who will live intelligently in this world must understand the laws and principles of physics." The algebra teacher, likewise, says, "Why just think of the economy of time and thought when one uses algebra instead of arithmetic. Everyone should certainly learn the elements of algebra if he wishes to be educated." Likewise, every subject matter enthusiast, seeing the undoubted values of the branch of knowledge which he espouses, makes himself believe that everyone would do well to know as much about it as he does.

The problem of determining what pupils need, however, is not so easy. Research studies have shown that pupils are not acquiring mastery of present curricular offerings in any great degree. To be sure, there are individual exceptions to this rule. If the school be recognized as primarily a selective agency to eliminate the many and point out the competent, present practice might be better justified. Our best scholars are undoubtedly competent in their restricted fields of knowledge. This is very specialized knowledge for them, however. Must we not provide educationally for all members of our population? It is manifestly a self-destroying practice which merely selects cer-

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* This paper was presented as an explanation and one interpretation of the work of the Research Committee of the Central Association of School Science and Mathematics Teachers at the annual meeting at Chicago, December 2, 1933.

[1] A. W. Hurd. *Cooperative Experimentation in Materials and Methods in Secondary School Physics.* Bureau of Publications, Teachers College, Columbia University, 1933. (Page 3.)

tain types of academic scholars and neglects the great mass. America has prided herself on the attention she gives to all. Therefore, we must not continue to practice the ideals of an aristocratic society by making no provision for those who do not care, and have no ability, for academic scholarship.

One of the seven cardinal principles of secondary education stresses the vocational aim as a primary aim of education. In the past history of our country, the curricula of our schools, though not vocational in aim except possibly for the clergy, did not hamper vocational selection. The great mass did not have a secondary education. Vocational opportunities were extensive enough to care for all persons without much specific educational preparation. Conditions are now quite different. Our density of population has increased with great rapidity. A compulsory universal education through the high school is almost upon us. Chance may no longer be depended upon to furnish a suitable vocation for everybody. There is, therefore, a greater necessity to concern ourselves with considerations of the possible future vocations of the pupils in our classes. It is evident that, for every individual, with the possible exception of health, vocation is the most vital problem. One of the theses of this discussion is that the school should give definite attention to individuals and aid them in as direct a manner as feasible in their efforts toward living healthful, happy, and useful lives.

It is in order then to ask ourselves with the educational philosopher,[2] "Why should any of the subjects at present in the curriculum be studied at all?" It is a weak answer to reply that knowledge of any kind is valuable and one may never know that it will not be of direct utility sometime. This is equivalent to swallowing a concoction of medicines with the hope that some of them may be of use sometime. The point is that the activities of every pupil should be planned because they are of direct utility to him. If followed to a logical conclusion, this would eliminate many of our school courses—probably most of our secondary school courses as they are now taught. If these implications are put into effect, what is to become of our present courses in science and mathematics? What will the school do to meet the needs of the pupils enrolled?

The investigation here reported was initiated to furnish factual data which might help in answering the above questions.

[2] Boyd H. Bode. *Modern Educational Theories*. The Macmillan Company, 1929.

Seven high schools in Ohio, Minnesota, and Illinois supplied data. Those from two of the schools are not included in the tables which were prepared for this report because they arrived after these tables were completed. They have been tabulated separately and in general are not in disagreement. The first prepared table[3] gives the weighted vocational choices of 1938 pupils enrolled in science and mathematics classes in the five schools in Ohio, Minnesota, and Illinois. Each pupil listed his first, second, third, and fourth choices. The choices were weighted by giving first choice a value of 4; second choice a value of 3; third choice a value of 2; and fourth choice a value of 1.

There are 217 vocational choices listed. Nineteen hundred thirty-eight pupils enrolled in science and mathematics classes have tentative plans involving at least 217 vocations. It is quite evident that these pupils have little idea of engaging in occupations restricted to science or mathematics. The five highest vocational choices in order of frequency of mention are: stenographic or secretarial work, aviation (flying), teaching, nursing, and medicine. If we consider the boys alone, the five highest vocational choices are aviation (flying), chemistry, medicine, engineering, and law. If the various kinds of engineering are combined, engineering ranks first with the boys. This excludes chemical engineering as this was included with chemistry If we consider the girls alone, the five highest choices are stenographic and secretarial, teaching, nursing, music, and art. There is a distinct leaning toward science and mathematics on the part of the boys. This is scarcely noticeable with the girls.

The second table prepared gives the highest 23 vocational choices in order of rank in biology, botany, physics, chemistry, and mathematics, respectively. It makes the matter of vocational choices more concrete for the specific courses. For biology pupils, the five highest ranking vocations are secretarial, aviation (flying), medicine, teaching, nursing; for botany pupils they are secretarial, teaching, music, nursing, and journalism; for physics pupils, law, aviation (flying), engineering, medicine, and business; for chemistry pupils, chemistry, aviation (flying), nursing, teaching, and secretarial; for mathematics pupils, secretarial, teaching, electricity, aviation (flying), and nursing. It is quite evident that if the science and mathematics courses are to concern themselves with the probable future vocations

[3] Copies of all tables in mimeographed form may be obtained in limited quantities by addressing the Institute of School Experimentation, Teachers College, Columbia University, New York City.

of the pupils as suggested by vocational choices, conventional courses now being offered must be considerably revised.

Studies have shown that there is a definite relationship between filial and parental occupation. A list of parental occupations might help to give a picture of future occupational status of pupils in our classes. A third table giving a list of fathers' vocations for the same 1938 pupils was prepared.

One hundred eighty-two different vocations of the fathers of the 1938 pupils are listed in the table. The highest five are business, salesman, factory worker, mechanic, and clerical.

A fourth table gives the 23 highest ranking fathers' vocations for the separate course divisions. Business and salesmanship stand highest in all groups. Physician ranks 6.5 among biology pupils; occupations relating to botany are not in the highest twenty-three among the botany pupils; engineer and mechanical engineer rank 12.5 each among the physics pupils (engineer would rank higher if all engineers had been combined); chemistry is not represented among the chemistry pupils; and engineer ranks 12.5 among the mathematics pupils with only business mathematics otherwise represented. If vocational choices indicated a possible need for course revision in science and mathematics, fathers' vocations suggest a much greater need. If pupils follow fathers' vocations to any great extent, science and mathematics will receive little representation from a professional standpoint.

If vocational choices indicate the interests of pupils as regards their visioned adult lives, their hobbies should give a picture of their recreational interests. These sometimes reflect also their consuming life interests which often lead to vocations. A fifth table prepared lists the hobbies of the 1938 pupils. The pupils gave the four hobbies in which they most indulged and these were weighted in the same manner as the vocational choices. The list should help teachers to plan for leisure time activities which are becoming more and more important in this age of increased leisure time. The highest ten hobbies, judged by frequency of mention (weighted) are reading, swimming, sports (unspecified), football, baseball, music, collecting stamps, skating, basketball, and tennis. If all sports were combined, they would easily rank first. One hundred sixty-seven hobbies are given. A sixth table gives the highest twenty-three hobbies in rank order for the separate courses.

The list for biology shows that the health objective might

be stressed considerably along the lines of interests in sports, cooking, and scout work. Interest in animals ranks 23 among the biology pupils. Gardening ranks 13 and nature study 21.5 among the botany pupils. Radio ranks 3, electricity 9, airplanes 13, aviation 17, machinery and auto-mechanics 19.5 among physics pupils. Chemistry ranks 22.5 among chemistry pupils. No direct mathematical interest is shown by hobbies on the part of mathematics pupils.

The data in all tables set clearly and definitely before us the question of how much weight in the choice of curriculum content should be assigned to occupational expectancies, and interests as disclosed by hobbies, of the pupils in our science and mathematics classes. Are we to continue to give them no thought or attention in our planning or are we to treat them as primary criteria for selecting our subject content and shaping our instructional procedures? The old controversy of subject versus pupils is again precipitated. Shall we direct primary attention on attempts to cover a certain amount of logically arranged subject-content in our conventional and traditional courses of study, or shall we concern ourselves more with the task of helping each individual to develop more completely his own inherent capacities and interests? There is grave question whether many high school teachers make studied efforts to learn much about the pupils in their classes. What personal interest is taken is likely to be but casual and directed toward individuals who are personally interesting. I contend that more of the attitude of guidance should be observed in the school room. This is quite different from the attitude of a scholar toward his subject, handing down instruction and driving pupils toward a goal of knowledge in subject-matter set by his own ideals of proficiency after several years of specialization in his chosen field.

If all of the conventional subject-matter were of vital functional use to every pupil, it would be much more important that he concentrate attention on its acquisition. A vocational survey course in the various science and mathematics fields would probably be worth much to most of the pupils. It is possible to so organize these courses that the vocational and leisure time objectives will be stressed. At the same time, pupils would be learning some logical subject-matter which might rightly be considered as a desirable concomitant of instruction but not a major objective as we now view it.

Frankly, I would like to see the bondage of the pupil to home-

work, subject-matter lesson-getting replaced by a reasonable survey and individual project plan of activity. The emphasis on lesson-getting oppresses the conscientious pupil because the tasks set are commonly beyond his powers to accomplish. Teachers may object to this statement but low school records in great quantity substantiate it without question. The lesson-getting program, on the other hand, encourages bluffing and deception of the part of the pupils who are not so conscientious. These pupils realize that the assigned lessons are not functionally important to them nor are the standards commonly set possible of attainment with the reasonable degree of effort which they may make considering the time needed for other activities in which they desire to engage. They are tempted to resort to various subterfuges to keep the instructor from knowing how inadequately they prepare their lessons. This is always the attitude assumed by individuals who are given tasks by those higher in authority. It is the servant-master attitude and only docile people commonly make good servants. If initiative and the capacity for independent action are to be developed, the usual lesson giving and getting program must be largely curtailed. After all the major excuse for its use in science or mathematics courses lies in two reasons, (1) the belief that hard work at any assigned task will bring out worthy character traits—in short, the value of discipline—and (2) the subconscious hope that a few great scientists or mathematicians may be the fruit of the process. There can be no doubt that much of the subject-matter now taught will never function in everyday life. In fact, there are voluminous records showing that most of it is soon forgotten probably because it is not used.

There are several methods of improving materials offered in science and mathematics courses which suggest themselves. Is it not a feasible thing to use the experimental method and try out some of these possibilities? One plan is that providing a list of minimum essentials for mastery by all pupils during the time set aside for class meetings. The restriction of class time for these essentials would result in a careful selection of content of a definitely functional nature. This selection can be accomplished partly by a concerted project by experienced teachers, such as constitute an Association like our own. Voluntary out-of-class activities of an individual nature are made possible by the saving of all out-of-class time for the development of a unified and integrated leisure-time program for every pupil. By

wise direction of this leisure-time extra-curricular program, desirable activities involving science and mathematics may be especially stimulated through the science and mathematics courses.

This is but one scheme among others that give promise of better instruction in science and mathematics. It is only by wise and intelligently planned experimentation that we may hope to find better materials and methods for use in our schools.

Reorganization of science and mathematics courses may have another effect which is very important. At present a large fraction of our secondary school population are not exposed to the science and mathematics offered in the senior high school These courses are commonly elective and have relatively small enrollments because pupils are either afraid on account of difficulty, or uninterested in the technicalities. There are indications that science or mathematics, or an integration of the two fields may soon be prescribed as required comprehensive courses extending through the senior high school. If so, reorganization is imperative. As teachers of science and mathematics, we have the great opportunity of working on reorganization so as to meet the needs of all secondary school pupils including those who do not now elect them. Survey and orientation courses are very much in the minds of progressive educators at present. They merit our careful study and investigation, for they suggest steps toward better organization of subject matter for school pupils.

SQUAT, FIN-BACKED ANIMAL RECONSTRUCTED AT AMERICAN MUSEUM

A prehistoric animal with a nearly flat body and head but with tall bony processes growing out of its backbone has just been pieced together from fossil fragments in the American Museum of Natural History by Dr. D. M. S. Watson, professor of zoology in the University of London, now visiting the American Museum of Natural History.

In front view this bizarre creature would have looked like an inverted T. It is about two feet long and the "fin" along the back is nine or ten inches high. Its name is Platyhystrix and it belongs to a very ancient group of amphibia that crawled along the slimy pond bottoms of the southwest 220,000,000 years ago.

Specimens with flat bodies and flat triangular heads like this one are well known from this period but the "fin" along the back is all wrong. So much so that when the late Prof. S. W. Williston of the University of Chicago first described this form several years ago, his fellow scientists would not accept his reconstruction.

Now Dr. Watson has proved he was right.—*Science Service.*

EASTERN ASSOCIATION OF PHYSICS TEACHERS

One Hundred Twenty-sixth Meeting

Byerly Hall
Radcliffe College
Cambridge, Massachusetts
Saturday, March 17, 1934

MORNING PROGRAM

9:30 Meeting of the Executive Committee.
9:45 Business Meeting.
10:00 Reports of Committees.
10:15 Address: "Recent Developments of Vacuum Tubes."
Prof. E. L. Chaffee, Harvard Univeristy.
11:00 Address: "Experimental Methods of Studying Cosmic Rays."
Dr. J. C. Street, Harvard Univeristy.
11:45 Description of the Equipment of the New Science Building at Radcliffe by Prof. N. Henry Black.
12:15 Luncheon at Hotel Commander. Price 75 cents.

AFTERNOON PROGRAM

A joint Meeting with the New England Section of the American Physical Society

2:00 to 4:00
Professor L. J. Henderson: "On the Difference between Physics and Physiology."
Professor N. H. Frank: "The Teaching of Elementary Physics in Engineering Schools."

OFFICERS OF EASTERN ASSOCIATION OF PHYSICS TEACHERS

President, Louis A. Wendelstein, High School, Everett, Mass.
Vice-President, Hollis D. Hatch, English High School, Boston, Mass.
Secretary, William W. Obear, High School, Somerville, Mass.
Treasurer, William F. Rice, Jamaica Plain High School, Boston, Mass.

BUSINESS MEETING

Mr. Charles E. Duffy of the Dorchester High School for Boys was elected to active membership.

Miss Elizabeth Richards of the Somerville High School was transferred from associative to active membership.

It was voted that the thanks of the Association be extended to Radcliffe College for its hospitality to us and also to the speakers who were on the program.

REPORT OF COMMITTEE ON CURRENT NEWS

Mr. John P. Brennan, *Chairman, Somerville High School*

Abbe Georges H. LaMaitre, the Belgian priest-astronomer who is now teaching at the Catholic University of America in Washington, has been awarded a prize of 500,000 francs in recognition of his work in the development of a theory of cosmogony, as the most important contribution to science made by a Belgian in the last year. His theory likens the galaxies of stars to the bubbles in a bowl of soapsuds all of which are moving away from each other at tremendous velocities under the impetus of an explosion of untold magnitude ages ago. Of this theory of LeMaitre Dr. Einstein has said: "It is the most pleasant, beautiful and satisfying interpretation of cosmic radiation; it has less objections and conjectures less contradictions than any other theory of the cosmic ray source!"

At Motor Boat Show recently held at New York, the Sterling Engine Company of Buffalo N. Y., marine engine manufacturers, exhibitd a new type of Diesel engine for which they claim a high efficiency with very low cost of maintenance. Weighing but 12.6 pounds per horsepower this new engine has no gaskets, crankshafts or connecting rods. The pistons move horizontally in the vertical plane of the drive shaft, and their motion is communicated to the drive shaft by an arrangement that has been developed from a design of the thrust bearings used on ocean liners.

Aluminum is now being used to coat the reflecting surfaces of reflecting telescope mirrors. The mirror to be coated is placed in a vacuum and the aluminum, vaporized by electricity, is allowed to condense on the surface of the mirror. Tarnish is of course harmful to all mirrors and silver tarnishes. Even an untarnished silvered surface does not reflect all the rays that fall on it, for example the ultraviolet rays. The aluminum coated mirror can be washed with soap and water.

Aluminum is being used also in the reconstruction of old bridges. In Pittsburg the steel floor system of a bridge was replaced by one employing aluminum alloys with a 65% reduction in the dead load and a corresponding increase in the live load. On the old bridge vehicles and their loads were limited to thirteen tons on four wheels; now twenty ton loads can cross the bridge. By this use of aluminum and the consequent postponement of the building of a new bridge, it is estimated that the city of Pittsburg has saved $1,564,875.

The production of artificial radioactivity has been announced by Professor Joliot of France and his wife Irene Curie, the daughter of the discoverers of radium. They bombarded boron with alpha particles and out of the boron came a stream of positrons. The experiments have been repeated and the findings of the Joliots confirmed at the California Institute of Technology.

REPORT OF COMMITTEE ON MAGAZINE LITERATURE AND NEW BOOKS

Mr. C. W. Staples, *Chelsea High School, Chairman*

BOOKS

Great Men of Science, by Philipp Lenard. Translated from German by H. S. Hatfield. Macmillan Co. N. Y. 1933. $3.00.

Lives and work of more than fifty prominent scientists of all nationalities, from Pythagorus to the present time.

The Universe of Light, by Sir William Bragg. The Macmillan Co., N. Y. 285 pages with preface and index. Illustrated.

A survey of light showing its new meaning to the sciences. The nature of light, the eye and vision, color and its origin, colors of the sky, polarization, light from sun and stars, Roentgen rays, wave and corpuscle theories. Written in clear style, yet not overpopularized.

Industrial Heat Transfer, by Alfred Shack. Translated from German. Wiley, 1933. 371 pages. (Copy in Boston Library.)

Set Catalogue and Index. Jan. 1921–1933, by John Francis. Rider, N. Y. 1933.

A list by makers of commercial radio sets built between 1921–1935. (Copy in Boston Library.)

Alternating Current Circuits, by M. P. Weinbach. Macmillan, 1933. 417 pages.

Automotive Engines: design Production Tests, 8th ed. of *Gasoline Motors* by P. M. Heldt. Nyack, N. Y. Heldt, 1933. 598 pages. Illustrated.

From Cave-Man to Engineer, by Waldemar Bernhard Kaempffert. Chicago, Lakeside Press, 1933. 128 pages.

The Museum of Science and Industry founded by Julius Rosenvald; an institution to illustrate the technical ascent of man.

Motion Picture Projection and Sound Pictures, James R. Cameror et al. Plates. Ed. 5. Woodmont, Connecticut, Cameron 1933.

"Communication with Electrical Brains" (Automatic Traffic Signals), by John Mills. *Bell Telephone Quarterly*. Jan. 1934. P. 47.

This is a chapter from *Signals and Speech in Electrical Communication* a book soon to be published.

MAGAZINE LITERATURE

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Astrophysics

"The Comet that Struck the Carolinas," *Readers' Digest*. Feb. p. 6. (Condensed from *Harper's Magazine*. Dec. 1933.)

"Lonely Outposts of Science Study Cyclones in the Sun," *Popular Science Monthly*. Jan. 1934. p. 14.

"Milky way found Source of Cosmic Radio-Waves," *Popular Science Monthly*. Jan. p. 30.

"How Astronomers Find Star Distances and Sizes," *Popular Science Monthly*. Jan. p. 34.

"The Indian Calendar," by Hansraj Gupta, *Popular Astronomy*. Feb. 1934. p. 82.

Atmosphere

"A Doctor Looks at Smoke and Dust," by N. W. McFarland, M.D., *Scientific American*. Feb. 1934. p. 66.

Aviation

"Cowling and Cooling" (Results of temperature tests on airplanes), *Aviation*. Jan. 1934. p. 13.

Wings Over the Tropics," by John F. Gregory, *American Travelers' Gazette*. Jan.–Mar., 1934. p. 18.

Electricity

"Resistance Lamps," by N. Insley, *Bell Laboratories Record*. Feb. 1934. p. 170.

"A Self-Contained Bridge for Measuring Both Inductive and Capacitative Impedances," by H. T. Wilhelm, *Bell Laboratories Record*. Feb. 1934. p. 181.

"Direct Current Conduction in Dialectrics," by E. J. Murphy, *Bell Laboratories Record*. Sept. 1933. p. 8.

"Spinning Towers Produce Electric Current from Wind," *Popular Science Monthly*. Jan. p. 18.

Gases

"Gases in Metals," by Earle E. Schumacher, *Bell Laboratories Record*. Sept. 1933. p. 17.

Gravitation

"The Force of Gravity on the Farm," *The Travelers' Standard*. Feb. 1934. p. 34.

Heat

"Refrigeration at Hoover Dam," *Ice and Refrigeration*. Feb. 1934. p. 85.

"Color Temperature of the B-Type Stars and Rayleigh Scattering," *Astrophysical Journal*. Jan. 1934. p. 1.

"The Temperature of Meteorites," by Charles Clayton Wyler, *Popular Astronomy*. Feb. p. 59.

"The Advantages of Welding," by Dr. K. Liedloff, Berlin, *Engineering Progress*. Jan. p. 9.

"A Collection of Errors," (Indirect Heater Installation), *Domestic Engineering*. Feb. 1934. p. 38.

Historical

"Isaiah Lukens" "Town Clock Maker and Machinist," by George H. Eckhardt. (Invented many things including first practical forerunner of speedometer), *Antiques*. Feb. 1934. p. 46.

"Patented Lamps of the Last Century," by Arthur H. Hayword, *Antiques*. Feb. 1934. p. 49.

"A Fragment of Industrial History," by H. V. Button, ("An electromagnetic machine"), *Antiques*. Feb. 1934.

"Early Sheet and Tin Plate Making," *Metal Industry*. Feb. 1934. p. 11.

"Engineering Achievements of 1933," by H. W. Reading, *The Electric Journal*. Jan. 1934.

"Furnace Heating Since 1835." (Illustrated), *Sheet Metal Worker*. Jan. 1934. p. 13.

Invisible Radiations

"X-Ray Examination for Metal Defects," by Lester E. Abbott, *Bell Laboratories Record*. Nov. 1933. p. 72.

Legislation

"The Revised Food and Drugs Bill—What it Means to You," by T. Swann Harding, (See also book *100,000,000 Guinea Pigs.*) *Scientific American.* Feb. p. 68.

Light

"The New Telescopic Mirrors," by Henry Norris Russell, *Sicentific American.* Feb. 1934. p. 80.

"Sundials and their Construction," *Scientific American.* Feb. 1934. p. 84.

"Un Pas decisif dans L'Eclairage.—Les Tubes "Vers Linsants," *L'Illustration.* Dec. 16, 1933. p. 523.

Magnetism

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Road Construction

"The German State Motor-Roads," by H. Seidel Udi, Berlin, *Engineering Progress*. Jan. 1934. p. 1.

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"Differential Pitch Sensitivity of the Ear," by R. Biddulph, *Bell Laboratories Record*. Oct. 1933. p. 45.

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"An Artificial Ear for Receiver Testing," by F. L. Crutchfield, *Bell Laboratories Record*. Nov. 1933. p. 81.

"A Quantitative Test for Tackiness," by J. H. Con, *Bell Laboratories Record*. Sept. 1933. p. 21.

"What is a 50 Pound Weight?" by Ralph W. Smith, *Scientific Monthly*. Feb. 1934. p. 111.

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Telegraph and Telephone

"Long Distance Telegraph Circuits," by T. A. Marshall, *Bell Laboratories Record*. Jan. 1934. p. 154.

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Prof. E. F. Chaffee of Harvard University discussed informally the enormous development in the production of radio tubes so that there are now a hundred different types. Starting with the two electrode tube the number of electrodes was increased up to four or five or more. Several of the more complicated ones are really a combination of the elements of several tubes in one bulb. The speaker pointed out the advantages and limitations of several of the well known types. He also presented an unusually interesting experiment in which the audience heard through a loud speaker the "noise of electrons arriving." Prof. Chaffee concluded with a stroboscopic study of waves in which the waves were projected on the screen so that all could witness the various phenomena.

Dr. J. C. Street of Harvard University presented from his own experience a very vivid story of the study of Cosmic Rays. He prefaced his remarks with an interesting statement of some of the difficulties which the investigator encounters. He made a survey of the kinds of apparatus used explaining with the aid of slides their construction and methods of operation. The talk was very informative to those fortunate enough to be present to hear it.

Prof. N. Henry Black of Harvard University gave a description of the new science building in which our meeting was held. He also presented the demonstrations described on pages 657-9.

ELEMENTARY PHYSICS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

By N. H. Frank
Massachusetts Institute of Technology

Elementary physics courses in universities and technical schools must be properly divided into two classes which make such different demands that they can hardly be discussed from a common viewpoint. In the first place, we have the general survey course in physics taken by students who do not intend to pursue scientific work and whose interest in physics (when such exists at all!) is of a purely cultural nature. These students usually have such little mathematical background that it is not possible to present much more than a course of extremely qualitative nature. It is not my purpose to enter into a discussion of this type of course, which for brevity we shall denote as academic physics, although I am fully aware of the serious problems which arise in planning and teaching such courses. We shall restrict our attention to the second type of elementary physics course, which we denote arbitrarily as technical physics. This course is studied by students who have the intention of pursuing scientific or engineering professions. Perhaps we might well distinguish between these two types of physics as physics for those who want to know something about physics and physics for those who need to use it in their professional work.

The fundamental role played by physics courses in engineering curricula has been repeatedly and continually emphasized. Following K. T. Compton, we may point out that one calls the engineering professions by such names as Civil, Mechanical, Electrical Engineering, etc., although they properly merit the name of Physical Engineering as a group. Certainly no serious student of Chemical Engineering would look upon a thorough training in chemical principles as a side issue in his education. Yet how often does the beginner in an engineering course look upon elementary physics as a burdensome requirement to be passed and forgotten, merely an obstacle in his path to the real "*practical*" engineering courses! Certainly a thorough grounding in the fundamentals of physics is as essential to the embryo engineer as to the physicist. In this connection the engineers could be of invaluable aid to those of us who teach these elementary technical physics courses by emphasizing this point. When such statements are made by physicists they are often looked on rather scornfully as a sort of propaganda by which the physicist tries to make his profession seem over-important.

Perhaps it is due to the fact that so many more students study the academic physics courses than the technical courses that the latter courses have received comparatively little attention. The preparation of the students entering the technical course should be more thorough, especially in mathematics. Unfortunately, this is not usually the case and this increases the difficulties encountered in teaching the course. We shall return

to this question of preparation more in detail at a later point. About three and one-half years ago it was decided to take a serious step in the direction of building up an adequate elementary physics course free, as far as possible, from so-called precedents which, in many cases, have more or less grown out of the experience in teaching of academic physics, and as such are irrelevant to technical physics. The elementary course required of all but a few of the M. I. T. students covers a period of two years, and the first study undertaken was that of the first year course. I shall speak in detail of the results obtained in this first year work although the same general principles must necessarily apply to the second year work.

I now come to the division of the material presented in the elementary work. It seems to be almost heresy to even consider any other division of physics than the classical compartments, mechanics, heat, sound, light, electricity and magnetism, but in spite of the historical precedent there are serious objections to such a division. For example, keeping physics strictly subdivided into compartments is almost sure to hinder the student from gaining an insight into the fundamental interconnections among these various divisions, not to mention the tragically serious handicap possessed by those who study physics in this fashion of failing to realize and utilize that unity of method and thought which pervades the whole field of physics. The need of a unified standpoint and method of utilizing physical principles is so essential for the technical course that it is clear that some modification of the classical treatment is necessary. We have developed a unified program in which the material to be taught in the elementary course has been grouped into two large subdivisions, each of these comprising the subject matter for one year's work. In the first division, which we arbitrarily will call Mechanics, is presented the material usually classified as point mechanics, rigid body mechanics, mechanics of continua, acoustics, and heat, the latter exclusive of the subject of heat radiation. In the second division of electrodynamics we group electricity, magnetism, heat radiation, optics and topics in modern physics. Within each of these courses there is attempted a coherent, logical treatment of the fundamental methods and principles of physical thought as applied to the fields mentioned above. Above all is the unity of method and the fundamental importance of general principles stressed in the presentation of the material. This, then, forms the general background of the two-year work in elementary physics.

Before discussing the more detailed aspects of the work, it is advisable to consider the previous preparation of the students. In the first place, this is far from uniform, and although many of our students come to us with a splendid background, unfortunately a large number of really able young men must labor under the handicap of inadequate instruction in secondary school mathematics and physics. Last fall we installed a scheme to try to remedy this inequality of background to some extent. At the end of the first five weeks of the semester, the freshmen who were obviously having difficulty in their studies were required to attend two extra exer-

cises a week which were conducted in the manner of tutorial sections to help fill the gaps in education of the relatively poorly prepared students. These sections were revised at the end of ten weeks and ceased to function at the end of the first semester. While it is still too early to form an adequate judgment, it seems that these additional exercises have helped considerably. One thing is certain, they clearly labeled the students who were definitely unable to continue work at the Institute. I might add that these sections were conducted in conjunction with the physics, chemistry and mathematics courses. For the purpose of the first-year physics course we are primarily concerned with the previous education of the student in mathematics and in the secondary school physics course. I cannot stress too much the need for sound mathematical ability at least in those subjects required for entrance. Indeed I should like to plead most fervently with the secondary school mathematics teachers to devote special attention to those students who intend to pursue scientific or technical work and to ground them in the fundamentals more thoroughly than the other students. The secondary school course in physics plays a unique role in shaping the ideas of the students, since it forms their first contact in most instances with the contents and concepts of physics, and any misconceptions here obtained are exceedingly difficult to correct and eradicate at a later stage in their education. If I may be allowed to utter a criticism of the average secondary school physics course, it would be that there is far too much problem solving with the help of disconnected formulas, and far too little stress placed on the concepts underlying these formulas and, even more important, on the range of applicability and limitations of these formulas. These points are so important that I should like to utter another plea at this point to the secondary school physics teachers to emphasize *correct* concepts. This does not mean to teach more advanced physics. To illustrate, let us consider the concept of centrifugal force, a phrase to be found on the tip of the tongue of every freshman. This so-called "tendency to move outwards" is confounded only too often with a real force, and worse, the continual use of this vague and improperly understood term forms a real obstacle in the way of a true understanding of Newton's second law of motion. If the fact that circular motion is an *accelerated* motion were stressed rather than the scheme of reducing a problem in circular motion to an equilibrium problem, how much sounder the student's understanding of the laws of motion would be. Surely no one would attempt to teach the concept of Coriolis' force to a beginner! Then why centrifugal force, its twin brother? To illustrate the second point concerning the special nature of simple examples, let us consider the exceedingly important concept of potential energy. I am entirely in accord with the accepted method of introducing this concept as energy of position or of configuration. But when illustrated by the example of a weight lifted from the earth's surface, how unfortunate it is to have the student *only* remember that potential energy is a weight times the height through which it is raised. The extent to which special formulas remain firmly embedded in the minds of

the students is amazing. After weeks of painstaking work in teaching the student more general, fundamental ways of analyzing problems, it is a common occurrence to find the student, especially in moments of great stress such as an examination, eagerly reaching back to special formulas in desperation rather than trying to apply the methods so laboriously taught.

I now turn to the actual instruction in our first year work. Underlying this is a fundamental theoretical basis which I may state consists of the belief that the student should be educated and not trained. Successful training may be often attained with a surprisingly small amount of understanding. Such training leaves the trainee unequipped to handle new problems and places the emphasis on the development of memory rather than of thinking powers. If one accepts the thesis that the education of the student should supply him with a thorough understanding of scientific principles and an ability to apply them, then it follows unequivocally that one must lay a broad basis in the first year work rather than intensive work in a comparatively narrow field of application of the principles of mechanics. Furthermore, if the fundamentals are to stand out clearly in the student's mind as distinguished from applications, care must be taken to present the material in an orderly, logical manner, always starting from fundamental principles, and never from special formulas in any application.

It is perhaps superfluous to point out the unqualified necessity of employing mathematical methods in carrying out such a program. Of course, qualitative arguments may and must be given, but without an intense study of the quantitative structure of physics and the important part played by mathematics in this study, the beginning course in physics is sure to leave the student wholly unqualified to enter into his professional work. In this connection the mathematics department of the Institute has been of invaluable aid to us in helping carry through our program. Without their hearty and enthusiastic cooperation we would be lost. The freshman starts his mathematics learning the ideas and rules of differentiation of polynomials and trigonometric functions and almost immediately thereafter the integration of these same functions. With this mathematical equipment in addition to the mathematics required for entrance it is possible to go ahead with our scheme.

Now to the actual structure of the course. The assigned time is divided into two lectures, two recitations, and one two-hour laboratory period per week for the whole first year. The laboratory work stresses the experimental aspects of physics, the recitations the applications of physical principles to quantitative problem work, and the lectures serve to tie both of these into a unified whole, expounding the principles and illustrating them with careful and numerous experimental demonstrations. There are several points of interest to be mentioned in connection with lecturing and lecture technique. Lectures should in general be given so as to amplify the discussion in the textbook employed, to present the ideas from new

angles, and, except in isolated cases, should not degenerate into a mere repetition of the material in the text. It is also an excellent plan to lecture without the use of lecture notes. This has a marked psychological advantage. A lecturer who must constantly refresh his memory by reference to notes invariably produces a reaction of the students expressed best, perhaps, by the following question, "How am I (the student) to be expected to learn this material when he (the lecturer), with so much more experience, must constantly look things up to see how they're done?" Perhaps the most important aspect of lectures in elementary physics is the experimental demonstrations, for emphasis must always be placed on the fact that physics is an experimental science. Care must be taken to point out that this does not mean mere experimenting, since a collection of facts, no matter how carefully ascertained, remains barren until interpreted and correlated by the principles and methods of physical science. Another important function of the lecture experiments is to stimulate interest in the course, for, after all, in a strict sense one can never really teach anything. The student must do the learning and the teacher acts as a guide and adviser in this process. And a student will never be willing to really work to understand physics unless a real interest in the subject is created. Carefully planned demonstrations can work wonders in this respect. There are interesting and uninteresting ways of doing the same experiments and I should like to illustrate by an example. In the discussion of resonance, it is a usual experiment to take two tuning forks of equal frequencies, usually with sounding-boxes, set one into vibration thus exciting the other, then stop the first and note that the second fork continues to emit a sound of the same pitch. While this experiment is not uninteresting, it often fails to be convincing, especially with a large audience, largely because the intensity of sound so produced is feeble and the two forks must be comparatively near each other to get any respectable results. The more interesting and stimulating manner of performing this experiment is to suspend a light ivory ball as a pendulum so that it almost touches one of the prongs of the secondary tuning fork. It is of advantage to show this part of the apparatus in shadow projection. With this set-up, one may then take the primary tuning fork as far away as possible in the lecture room, set it into vibration and the sound wave will set the secondary fork vibrating. This latter motion starts the ivory ball moving so that it is clearly visible and provides visual evidence for the mechanical motion of the secondary tuning fork. How much more convincing this second mode of showing the same experiment and how much more stimulating to the audience! Of course, special problems arise due to the large audience in the lectures (about 250). Apart from the administrative problems inherent in the instruction of such large groups, the problem of designing demonstrations so they may be seen by all the students is important. Up to a certain point one can perform certain experiments on a larger and larger scale, but there is a limit in this direction, and the best solution in many cases seems to be to revert to small-scale experiments and show them

in projection. Whenever possible, quantitative experiments should be performed in preference to qualitative ones even if the obtainable precision is not large. After all, if one stresses the importance of the quantitative aspects of physics, no opportunity should be lost in bringing this home in the demonstrations. As a final point in connection with these demonstrations, one must be careful in striving to create interest not to go too far in the direction of sheerly spectacular experiments. Every demonstration should be planned to illustrate something definite in the understanding of the principles.

In this connection the laboratory work should coöperate. Laboratory experiments should be as precise as possible without excessive complication and the technique of making careful measurements must be taught. On the other hand, no student should ever be allowed to perform an experiment without having to interpret the results of his measurements in terms of physical principles. Indeed we have tried to design all our experiments so that they never become merely a means of measuring a given quantity, but rather that they provide a means of experimentally verifying principles. For example, the ballistic pendulum can be used as a device to measure the velocity of a projectile. But how much more important is it to perform this experiment with the idea of experimentally verifying the laws of conservation of momentum and of mechanical energy.

The class-room work is carried out in small sections of about 25 students in which quantitative problem work is discussed to exemplify the utility of the principles. Very often theoretical understanding of physics is most clearly and readily obtained by seeing how the principles are applied to and lead to an answer in special examples. This phase of the teaching is best handled in these smaller sections. It is important in these sections that one teaches ordered methods of solution of all problems, no matter how trivial they seem, starting in every case with a statement of the physical principles relevant to the particular problem and never from a special formula. Special tricks are in general to be avoided in elementary courses especially where they have decidedly limited range of application, and general systematic methods of attack employed. The students often balk at the idea of solving problems by "hard" methods when their "common sense" reasoning seems to lead more quickly and easily to the correct answer. This feeling can be avoided by pointing out how problems insoluble by "common sense" methods fall quickly into line when a systematic application of general principles is employed. In this connection the type of problems assigned to the students can be of considerable help. Problems of a type which amount to a substitution of numbers into a formula to be found on a page of the text must be avoided, as must a series of problems which consist of repeating an identical calculation a number of times with different numerical values of the data involved. I fully realize the difficulty and arduousness of the work involved in making up problems which really call for thought on the student's part without being so involved that they create unnecessary and troublesome mathematical complications.

Yet any time spent in such a direction is well worth while and this aspect of the work must not be neglected.

The problem of the scope of the course is a difficult one. A wide scope of material to help fix the fundamental principles of mechanics is desirable and yet there are limitations as to how far one may go in such a course. The fact that we use calculus methods from the outset increases our range enormously and it is important to take advantage of the increased possibilities in this direction. Furthermore, I believe it is impossible to predict a priori how far one can successfully go with freshmen, and the only way to find out is to try. This is not an easy task and causes hardships which are unfortunate but not too serious. The hardships arise due to the fact that the first attempt must go further than advisable in the finished product and then one must trim the edges until a safe limit has been reached. It is clear that this method is much more effective than trying to add things to a too limited course. The latter scheme would make it impossible to maintain the logical close-knit unity so valuable in such a course, and a complete revision from the beginning each time a new topic is introduced is obviously a waste of energy. It turns out that the possible scope of the course is very sensitive to the morale of the students, and when it is possible to maintain good morale, it is astounding how far one can go with freshmen to advantage. It has been our decidedly pleasant experience to find that quantitative methods can be pushed much further than we thought possible at the outset. As mentioned, the reaction of the students bears careful watching, and emphasis must be placed on the progress made by the student rather than on his shortcomings. I believe the proper attitude for the teacher is to agree with the student when the latter complains that the physics course is hard, and to spend his efforts pointing out that while it is hard, it is worth while, and that things attained by hard work are the lasting, worth while things.

As our course now stands we cover the following material in the first year's work. We start with a study of linear kinematics, followed by plane kinematics, a statement of Newton's laws and applications to problems in the statics of a particle, linear and plane particle dynamics, work and energy, and, as a last chapter in dynamics of a particle, certain special motions such as simple harmonic motion are treated in some detail. Following this, rigid body statics, translation, rotation and rolling of rigid bodies in plane motion and special rigid body motions, with an introduction to the vector nature of torque and angular momentum. Planetary motion and gravitation provide an introduction to the concept of force fields to be used in connection with the mechanics of continuous bodies. The latter is divided into hydrostatics, hydrodynamics, including a qualitative discussion of turbulence and vortex motion, static elasticity, and wave motion in elastic media with applications to acoustics. As a last subdivision a number of topics in heat are considered starting with thermometry, a formulation of the first law of thermodynamics, heat conduction in the steady state, application of the first law to perfect gases, elementary kinetic theory of perfect gases, and the properties of real gases.

As a final chapter a very elementary introduction is given to the second law of thermodynamics.

In connection with the work outlined, every possible chance to link together various parts of the subject is utilized. For example, in the discussion of topics in heat, constant reference is made to the atomic picture and elementary mechanical calculations made to tie up with the thermodynamic standpoint. Furthermore, every effort is made to correlate things learned in the secondary school courses. For example, practically every student has been taught and has remembered that the velocity of sound in air at room temperature increases by 2 feet/second per degree Centigrade rise in temperature. This isolated fact is fitted into the scheme of things as follows:

1. Sound waves in a gas are discussed as mechanical motion of an elastic medium and the velocity of such waves is calculated by applying Newton's law of motion.
2. The definition of compressibility first introduced in elasticity is made more precise in the heat section by calling attention to isothermal and adiabatic compressibilities.
3. The compressibilities of an ideal gas are calculated and it is shown that sound waves are adiabatic.
4. The gas law is used to express this velocity as a function of absolute temperature.
5. From this result the numerical value quoted above follows by a simple calculation. Such connections as these go a long way in organizing the student's knowledge and help him get a feeling for the utility of general principles as opposed to special methods.

Before closing I must make some mention of an entirely different but important problem confronting us in the elementary physics instruction. This is the problem of what to do with students who have transferred to the Institute after one or more years in other colleges or universities. These students come to us, in general, having completed a one-year survey course in physics of the academic type and consequently do not fit into any course of the regular two-year elementary physics at the Institute. It has been found necessary to give these men special instruction and a course has been designed which has as its object the rounding out of this one-year training into the equivalent of our two-year work with special emphasis on the application of mathematical methods in physics.

Finally, it should be remembered that the process of education is dependent on repetition and one must not hope for too much in the way of mastery by the students of the subject matter treated in a first course. If care is taken, however, in subsequent courses depending on the elementary physics to repeatedly apply the same fundamental principles to such problems as may be relevant in these courses, it seems to me that by this method one can most nearly approach the ideal result of turning out a graduate who has mastered the fundamentals of physical science to an extent where he can apply them efficiently to those problems presented by his particular work.

TWO PIECES OF NEW APPARATUS

By N. Henry Black
Harvard University, Cambridge, Mass.

First I will show you this small sodium-vapor lamp which furnishes an unusually brilliant monochromatic light, and is very useful for many experimental purposes. The brilliancy of the lamp is about 20 times that of an ordinary sodium flame and it is remarkably steady. With this as a source, one can project on a screen the bright-line spectra of metallic sodium. In fact, we have arranged our own projection apparatus so that we may show the dark absorption line of sodium and at the same time immediately above the dark line the bright yellow lines. With a direct-vision spectroscope you can detect several sodium lines besides the usual D lines. This is because of the high temperature in the arc.

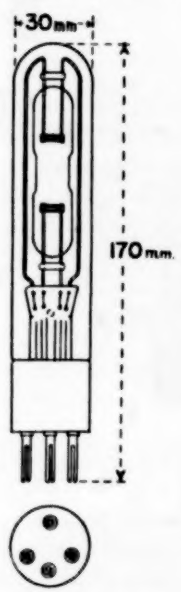


Fig. 1. A small sodium-vapor lamp.

The lamp itself (Fig. 1) is a cylindrical glass tube about 13 cm. long and 3 cm. in diameter. There are two heating coils near the ends of the tube. In starting the lamp the current is first switched to these coils and then after glowing about a minute the coils become electrodes for an arc, which soon vaporizes the metallic sodium within the tube. There is a little neon gas in the tube. The lamp has a double wall with a vacuum in the intervening space to prevent loss of heat. The glass of the inner wall has to be of an especial composition to prevent the loss of sodium through the glass walls.

The base of the lamp bulb is provided with four terminals much like our ordinary radio tubes. There is a special base and socket with switch for starting and running. It takes about 1.2 amperes and on the ordinary 110 alternating current line requires a 70-ohm rheostat in series. This particular lamp was purchased from E. Leybold's Nachfolger A-G., Cologne, Germany. The bulb cost $12.50, the base socket and switch $3.50 and a suitable rheostat $3.00, plus duty and transportation charges.

In this country the General Electric Company has recently brought out a large model (2AMiTB2) of this sodium-vapor lamp for street lighting. It furnishes 10,000 lumens and is probably 2 or 3 times as efficient as our best incandescent lamps. Some investigators claim that this monochromatic light produces less image distortion in the eye than the ordinary "White" light and this gives greater acuity of vision (perhaps 2 or 3 times).

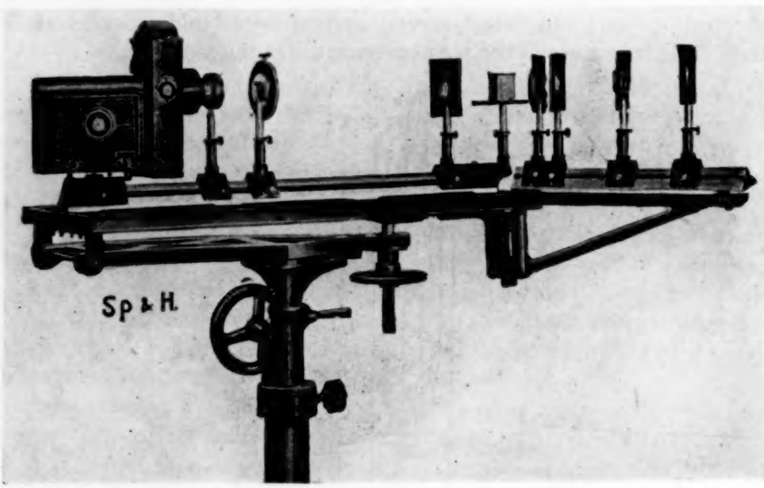


Fig. 2. Pohl's Optical Bench set up for color mixing.

The second piece of apparatus which I wish to show you is the new form of optical bench (Fig. 2) designed by Professor R. W. Pohl of Göttingen University and manufactured by Spindler & Hoyer. The whole apparatus is placed on a low movable table, which is a great convenience. The foundation of this optical bench is a triangular iron base which has long been used by Zeiss in their optical apparatus. The source of light is a 5-ampere arc lamp using small carbons to get nearly a point source of light. The accessories, such as the condenser, slit, lenses, prism, etc., are each supported on a saddle which is easily removed or which may be fixed firmly by a set screw.

In order to illustrate some of the uses of such an optical bench, I have arranged the apparatus to project a continuous spectrum, and the compli-

mentary colors and the mixing of these prismatic colors. The diagram (Fig. 3) shows the arc lamp at the left end, and then proceeding to the right, we have the condenser, a converging lens ($f=20$ cm.) to concentrate the light on the slit, then a second converging lens ($f=15$ cm.), and an equiangular flint-glass prism at the right-hand end of the bench. This gives us the continuous spectrum. Then comes a diaphragm with an adjustable

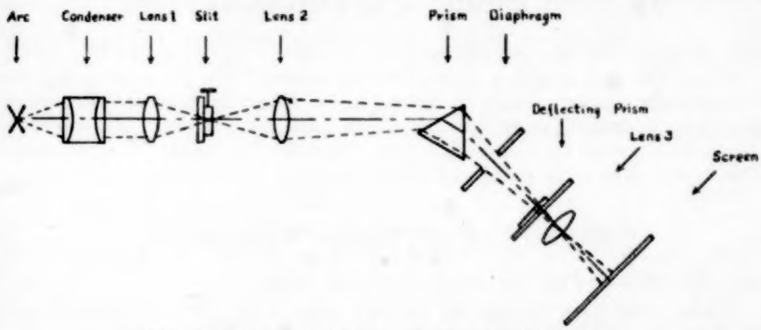


Fig. 3. Diagram of "set-up" for mixing colors.

aperture on the extension of the bench and a converging lens which forms on the screen a clear sharp image of the aperture in the diaphragm. This image is pure white since it is made by combining the prismatic colors. If now we insert an opaque object, such as a pencil, in the beam near the last lens, we cut off a portion of the spectrum and get the complementary color projected. If we insert two small deflecting prisms so as to intersect portions of the spectrum, we get three colored disks projected on the screen. These disks may be made to overlap by changing the aperture in the diaphragm. This is an excellent method of mixing colored lights.

SCIENCE QUESTIONS

June, 1934

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

Readers of School Science and Mathematics are asked to contribute: Questions, Answers, Comments, Suggestions—Whatever is new or interesting in the teaching of Science.

Wanted—Your examination papers and tests. Thanks! Mail them.—Do it now.

WHY DOES THE HEART KEEP ON BEATING?

662. *Proposed by Florence E. Clippinger, Roosevelt H. S., Dayton, Ohio*

Here is an item which may be of interest for you to print in your magazine.

On Tuesday Feb. 28, 1934 as soon as I came to school I placed a turtle under chloroform. That was about 8 o'clock. I would judge it was dead by

8:30. Then I dissected it and the heart was still beating when the night janitor left at 11 o'clock Wed. night making $38\frac{1}{2}$ hrs. We do not know how long it beat after that but it had stopped when I came to school Thursday morning.

I would be glad to know if anyone had a similar experience or if they have been known to beat longer than that.

AN AUTO ENGINE A CHEMICAL FACTORY

663. *Suggested by the "Automobile Buyer's Guide"—General Motors—1934*

Why is the auto engine a little chemical factory? (By the way, to get an "Automobile Buyer's Guide" write to H. G. Weaver, Director, Consumer Research, General Motors, Detroit, Mich. Also, ask for their "gas engine" charts. No charge for either. Mention "Science Questions." Thank you! This is *not* paid advertising.—F.T.J.)

ENERGY DISAPPEARS—WHERETO?

664. *Proposed by Phil Shickman, Laurium, Mich.*

Having read your articles on various subjects in "School Science and Mathematics," *I would like information about the following subject:*

An iron spring is dissolved in sulphuric acid, being coiled in such a manner that it does not unwind when immersed in the acid. How does the energy used to compress the spring release itself, (in what form) according to the law of conservation of energy? Also, in attempting to verify the answer by experiment, how is it possible to keep the spring in a compressed state as the acid constantly decreases its surface?

Please supply an experimental answer and also theoretical.

WHY THE FAILURES?

665. *Proposed by Carlton D. Blanchard, Norwich Free Academy, Norwich, Conn.*

Enclosed is a copy of our Mid-year exam in Chemistry. I should like to receive through your column the reactions of teachers who would be good enough to criticize it. We feel that it failed more pupils than it should have.

Chemistry A. Norwich Free Academy, Jan. 1934.

1. What is the distinction between pure and applied chemistry? (2)
2. Describe the laboratory experiment on chemical and physical changes. How are we sure that a chemical change had taken place? (5)
3. What is the chemical distinction between a mixture and a compound? (4)
4. What two facts about burning did Lavoisier prove? (2)
5. Write word equations to show three methods of preparing hydrogen (6)
6. Explain what is meant by the reducing action of hydrogen. (2) Name another reducing agent (1)
7. Define diffusion. State the kinetic molecular theory (5)
8. Mention three methods of purifying water and tell what each accomplishes (6)
9. What is the test for carbon dioxide (2)
10. State Law of Multiple Proportions and illustrate by example (5)

11. Describe the Laboratory Experiment on Preparation and Properties of Nitrogen (5)
12. State two proofs to show that air is a mixture (2)
13. Define simple replacement and write an equation to illustrate synthesis (5)
14. How many grams of CO_2 can be liberated from 200 grams of calcium carbonate? ($Ca^2=40$, $C=12$, $O=16$, $H=1$, $Cl=355$) (5)
15. Discuss the Laboratory preparation of chlorine giving equation (6)
16. Give the test for a chloride, a sulphate (6)
17. Discuss the properties and chemical behavior of sulphur (4)
18. Write the equation for the complete combustion of hydrogen sulphide (3)
19. State the characteristics of an acid (3)
20. Write the equation for preparing calcium chloride by neutralization (4)
21. Discuss the naming of acids and bases (4)
22. Define molar solution, indicator (4)
23. Prove that the hydrogen molecule has two atoms (6)
24. Define basic anhydride and given an example of an acid anhydride (3)

COMMENT AND A QUESTION

666. *Proposed by Brother Francis, LaSalle Institute, Cumberland, Md.*

The boys of the Eighth Grade solved Brother John's "Fly" Problem (No. 646). They find such problems very interesting. They request that you print more of such a nature.

May I propose a little question in regards to this problem? How many times did the fly touch the front wheel of each bicycle before being crushed to death?

A MAGNET'S POLES

667. *Proposed by H. Hansen Smith, Battle Creek, Iowa.*

a. How many poles may a magnet have?

b. If one end of a bar magnet were split and spread to form a "*Y*," how many poles would there be and where would they be located?

A BYRD OF A QUESTION! AND ANSWERS

647. Here is a clipping from a recent issue of the *Chicago Herald and Examiner* telling what Admiral Byrd found when he reached "Little America." What type of lighting system is in use?

"Somebody cranked the phonograph, and at the first strain of music, Byrd burst into laughter. The tune was 'The Bells of St. Mary's.' Quin Blackburn used to play it twenty times a day, and he still likes it!

"Petersen idly flipped a switch and the lights of the building went on. He pressed the telephone connection in the Administration Building. Dr. Poulter picked up another phone. After four years, everything worked."

By Brother Fracis, LaSalle Institute, Cumberland, Md.

The answer is "Batteries."

645. *Additional solutions from Margie Dalton and Marvin Strick, Hirsch H. S., Chicago; C. W. Trigg, Cumnock College, Los Angeles, Calif.*

646. *Additional solutions from Frank Kurtz, Chicago; Charles W. Trigg, Los Angeles, Calif.*

WHICH IS COLDER?

In the March, 1934, number of School Science and Mathematics *Alden M. Shofner asked about the reading of the thermometer frozen in a block of ice (Question 645) when the air temperature is −10° F.*

Here is another along the same line.

650. Ohio has had an unusually severe winter with successive days on which the temperature has been away below zero.

a—There is ice about 22 inches thick on Lake Erie. What is the temperature registed by a thermometer frozen in Lake Erie ice when the air temperature is −20° F.?

b—A pail of water was left standing beside the iron pump overnight when the temperature dropped to −15° F. The ice froze solid and bulged the pail. What temperature would you expect the iron pump to show, the pail, the cake of ice in the pail? Why?

c—A maple tree stood in the same yard. What temperature would you expect in the heart of the tree?

Answered by Marc Cutler and Frank Gardner, Brookline High School, Brookline, Mass.

(*a*) The temperature at any point is directly proportional to the depth of the ice at the point. The temperature at the top of the ice must be −20° F. and at the bottom 32° F., therefore the temperature at any in between point must be in proportion. This difference of temperature which is maintained at two points quite close together can be explained by the insulator effect of thick ice. It is made use of in eskimo igloos.

There comes a time when the ice is so thick that its conductance becomes very small like asbestos. Incidentally the ice on a lake stops freezing at this point. An insulator, such as asbestos, or ice as in this case, is a substance whose temperature doesn't alter appreciably which changes in temperature of adjacent bodies (or parts of itself). Therefore we can conceive the gradual change in temperature from −20° F. at the top to 32° F. at the 22 inch depth.

Answered by Margie Dalton, Hirsch High School, Chicago, Ill.

(*b*) All would be −15° F., because the three are crystalline substances which after crystalizing may become colder according to the surrounding temperature.

(*c*) The temperature at the heart of the tree would be −15° F., because although the tree has not discontinued living during the winter, it still is not active enough to keep its heart from going down to the surrounding temperature. Its bark wood, is a poor conductor of heat but would not keep the heart of the tree warm through a long cold period.

651. *Proposed by Alden M. Shofner, Shelbyville, Tenn.*

Some old soldiers tell me that they made their bed on the cold dry

ground, on some quilts, and covered over with quilts, and while sleeping came a big snow, and soon the weather changed hurriedly and went to 10 degrees below zero, but that they slept warm till late next morning. Now the snow kept off the coldness, why not ice?

Answer by Frank Kurtz, Hirsch High School, Chicago, Ill.

The snow, like wool, is porous and the air makes it a poor conductor of heat. But ice is not porous so it conducts the heat off.

Also answered by Margie Dalton.

PUSH AND PULL

652. *J. C. Parckard, Brookline, Mass. "Here's my entrance fee for 1934."*

Two boys are pulling in opposite directions, with a force of 200 lb. each upon a rope stretched between them. What is the tension on the rope? If one of the boys increases his pull to 300 lb., while the other boy keeps his at 200 lb., what, then, will be the tension on the rope? Explain.

Solution by Frank Kurtz, Hirsch High School, Chicago, Ill.

When each boy pulls with a force of 200 lb., the tension on the rope is 200 lb.

One boy increases his pull to 300 lb. while the other boy's remains at 200 lb. The problem is like Atwood's machine and using the formula the tension on the rope is found to be 240 lb. The 40 lb. over 200 lb. is used to accelerate the one boy while the 60 lb. under 300 lb. is used to accelerate the other boy.

Solution by Eliot Silverman, Brookline High School, Brookline, Mass.

(*a*) 200 lb.

Every pull must be opposed by an equal and opposite pull (Newton's Law). In practice we never consider the *passive* pull only the *active* one.

(*b*) 200 lb.

If two forces are opposed the registered effect can be only as great as the smaller force (Newton's Law).

GORA (GUILD QUESTION RAISERS AND ANSWERS)

(Qualifications for Membership: At least one contribution per year.)

29. Marvin Strick, Hirsch H. S., Chicago, Ill.
30. Carlton D. Blanchard, Norwich Free Academy, Norwich, Conn.
31. Margie Dalton, Hirsch H. S., Chicago, Ill.
32. Frank Gardner, Brookline H. S., Brookline, Mass.
33. Eliot Silverman, Brookline H. S., Brookline, Mass.
34. Marc Cutler, Brookline H. S., Brookline, Mass.
35. Frank Kurtz, Hirsch H. S., Chicago, Ill.
36. Arnold Bookheim, Williamson Central School, Williamson, N. Y.
37. Brother Francis, LaSalle Institute, Cumberland, Md.
38. Florence E. Clippinger, Roosevelt H. S., Dayton, Ohio.
39. Phil Shickman, Laurium, Mich.

PROBLEM DEPARTMENT

CONDUCTED BY G. H. JAMISON
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Drawings in India ink should be on a separate page from the solution.

2. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

3. In general when several solutins are correct, the one submitted in the best form will be used.

1328. *Proposed by Charles Louthan, Columbus, Ohio.*

Find the nature of the path of a point P, 2 in. from the center of a circle M, of diameter 20 in. as M rolls internally on a circle of radius 20 in.

Solution by Roy MacKay, Albuquerque, N. M.

Consider a set of rectangular axes so chosen that the point $P' \equiv (a+b, 0)$ is the initial position of a point at a distance b from the center of a circle M of radius a which rolls internally on a circle with center at the origin 0 and radius $2a$. Let $P \equiv (x, y)$ be any other position of P'. Draw MP and produce to cut the circle M at Q. Then from the figure,

$$x = OK + KR = a\cos\theta + b\sin\left(\frac{\pi}{2} + \theta - \phi\right), \text{ and}$$

$$y = KM - ML = a\sin\theta - b\cos\left(\frac{\pi}{2} + \theta - \phi\right).$$

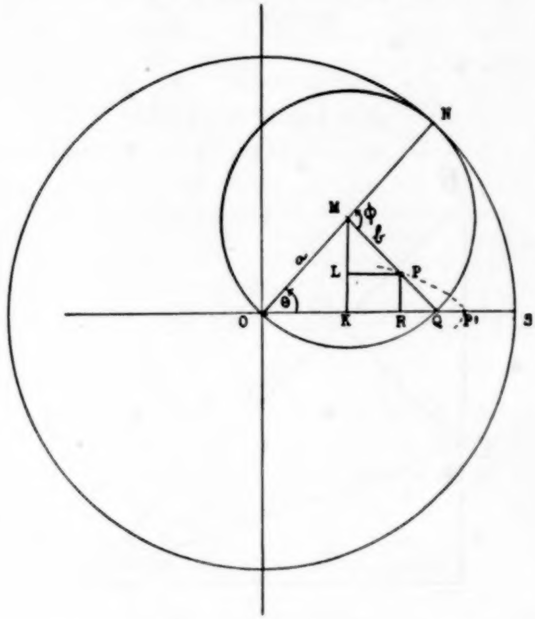
By our choice of axes the initial position of Q is the point of contact of the circle M with circle 0. Since the hypocycloid generated by Q is the segment $(-2a, 0)(2a, 0)$ of the x-axis (See, for example, Osgoode, *A First Course in Differential and Integral Calculus*, p. 150.) arcs QN and SN are equal length; that is

$$a\phi = 2a\theta \qquad \text{or} \qquad \phi = 2\theta.$$

Hence

$$x = a\cos\theta + b\cos\theta = (a+b)\cos\theta,$$
$$y = a\sin\theta - b\sin\theta = (a-b)\sin\theta,$$

which is the equation of an ellipse with center at the origin and having $a+b$ and $a-b$ as semi major and minor axes, respectively.



Now the conditions of the problem at hand specify that $a=10$ in. and $b=2$ in. and thus the equation of the ellipse may be written

$$\frac{x^2}{144}+\frac{y^2}{64}=1.$$

Also solved by Charles W. Trigg, Los Angeles; W. E. Buker, Leetsdale, Pa.; H. Hansen Smith, Battle Creek, Iowa.

1329. *Proposed by the Editor.*

Prove that for $0<\theta<45°$ $\cot\theta+\cot(45°-\theta)>4$.

FIRST SOLUTION

Solution by Edgar A. Rose, Rochester, N. Y.

Let $$\cot\theta+\cot(45°-\theta)=y.$$

Then $$\frac{dy}{d\theta}=-\csc^2\theta+\csc^2(45°+\theta)$$

and $$\frac{d^2y}{d\theta^2}=2\csc\theta\cot\theta+2\operatorname{scc}(45°-\theta)\cot(45°-\theta)$$

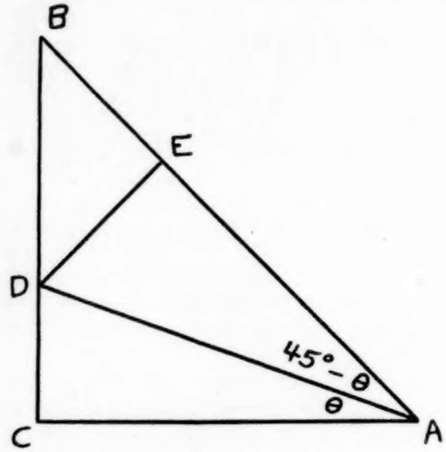
setting $$\frac{dy}{d\theta}=0 \quad \text{gives} \quad \csc^2\theta=\csc^2(45°-\theta)$$

whence $$\theta=45°-\theta$$

and $$\theta=22°30'.$$

Substituting this value in

$$\frac{d^2y}{d\theta^2} \text{ gives } 4 \csc 22°30' \cot 22°50'$$



which is positive making 22°30′ a minimum. Substituting this value of θ in the original, we have

$$2 \cot 22°30' = 2(2.4162) = 4.8282 \quad \text{or} \quad 2(1+\sqrt{2}).$$

Therefore we could have had 4.8282 in the statement rather than 4.

Second Method

Solution by Charles W. Trigg, Los Angeles, Calif.

In the isosceles right triangle ABC draw any line from A cutting BC at D. Draw $DE \perp AB$.

$$AC=BC, \quad DE=BE, \quad BA=AC\sqrt{2}, \quad BD=BE\sqrt{2}.$$
$$\angle BAC=\angle B=\angle BDE=65°,$$
$$\angle DAC=\theta<45°, \quad \angle EAD=45°-\theta.$$

$$\begin{aligned}
M&=\cot\theta+\cot(45°-\theta)\\
&=\frac{AC}{DC}+\frac{EA}{DE}=\frac{BD+DC}{DC}+\frac{BA-DE}{DE}\\
&=\frac{BD}{DC}+1+\frac{BA}{DE}-1=\frac{BD}{DC}+\frac{BC\sqrt{2}}{DE}\\
&=\frac{BD}{DC}+\frac{2(BD+DC)}{\sqrt{2}\cdot DE}=\frac{BD}{DC}+\frac{2(BD+DC)}{BD}\\
&=\frac{BD}{DC}+\frac{2DC}{BD}+2=K+\frac{2}{K}+2. \qquad \left[\text{Where } K=\frac{BD}{DC}\right].
\end{aligned}$$

If $K<1$, $M>4$; $K=1$, $M=5$; $1<K<2$, $M>4$; $K\geqq 2$, $M>4$.

$$\therefore \quad \text{when } \theta<65°, \quad M>4.$$

Also solved by Cecil B. Read, Wichita, Kan.; Roy MacKay, Albuquerque, N. M.; Craig Smith, Missoula, Mont.; O. K. DeFoe, St. Louis, Mo.; B. Hugh, Indianapolis, Ind.; W. E. Buker, Leetsdale, Pa., and Aaron Buchman, Brooklyn, N. Y.

1330. *Proposed by Margaret Joseph, Milwaukee, Wis.*

In making war bread a mixture of rye and corn meal was used. From 100 lbs. of rye flour a certain amount was taken and replaced by corn meal. Later, from the mixture the same amount was removed again replaced by corn meal. The resulting mixture was 16 pts. rye to 9 pts. corn. What were the proportions of the first mixture?

Solution by Cecil B. Read, The University of Wichita, Wichita, Kan.

Let $\qquad x=$ no. of lbs. removed

$$\frac{100-x}{100}=\text{percent of rye in first mixture}$$

$$\frac{100-x}{100}\,x=\text{no. of lbs. of rye removed at second removal.}$$

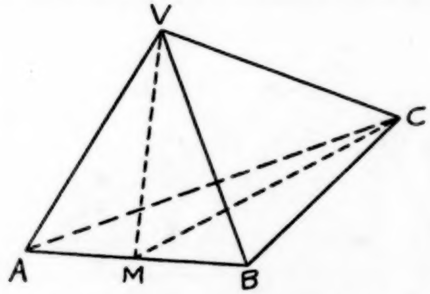
$$\frac{100-x-\dfrac{100x-x^2}{100}}{100}=\text{percent of rye in second mixture.}$$

But by the problem the last quantity is equal to 16/25. When we simplify and solve, we obtain $x=180$ or $x=20$, the first value obviously impossible. Hence the first mixture was 80 parts rye to 20 parts corn, or 4:1.

Also solved by W. E. Buker, Leetsdale, Pa.; Roy MacKay, Albuquerque, N. M.; Charles W. Trigg, Los Angeles; J. O. Austin, Cowden, Ill.; Aaron Buckman, Brooklyn, N. Y.; O. K. DeFoe, St. Louis; M. Freed, Wilmington, Calif.

1331. *Proposed by W. E. Buker, Leetsdale, Pa.*

Prove or disprove that the altitudes of a tetrahedron are concurrent.



Solved by Charles W. Trigg, Cumnock College, Los Angeles, Calif.

Let $VABC$ be a tetrahedron with face $VAB \perp$ face CAB, $VA=VB$, $CA=CB$.

The altitude from V will lie in the face VAB and will bisect AB at M.

The altitude from C will lie in the face CAB and will bisect AB at M. If the altitudes are concurrent, the altitudes from B to VAC and from A to VBC will pass through M and hence will coincide with AB and themselves be coincident. Then AB will be perpendicular to faces VAC and VBC, which are therefore coincident or parallel. Since VC is common to both faces, they are not parallel. Since A and B are distinct, the faces are not coincident. Hence the altitudes from both B and A do not pass through M.

Therefore the altitudes of all tetrahedrons in general are not concurrent.

Also solved by Roy MacKay, Albuquerque, N. M.; Abraham M. Glicksman, New York City; Balfour S. Whitney, Norman, Okla.; Aaron Buckman, Brooklyn, N. Y.; Craig L. Smith, Missoula, Mont.; H. Hansen Smith, Battle Creek, Iowa.

1332. *Proposed by O. K. DeFoe, St. Louis, Mo.*

Consider a clock whose hour, minute, and second hands rotate about a common axis. At what time after twelve o'clock will the hands make equal angles with each other, i.e., angles of 120 degrees?

Solved by H. Hansen Smith, Battle Creek High School, Battle Creek, Iowa

The hands will never make equal angles with each other.

There are 22 places on the dial at which the minute and hour hands make an angle of 120 degrees. By computing the fraction of the minute in each case and locating the position of the second hand, it is found that the second hand is never in such a position.

Would be approximated more closely if the second hand were at exactly 20° with the minute hand and the hour hand a little off $\approx \frac{1}{600} \times 10\frac{10}{11}°$.

The times at which this situation is approximated most closely are:

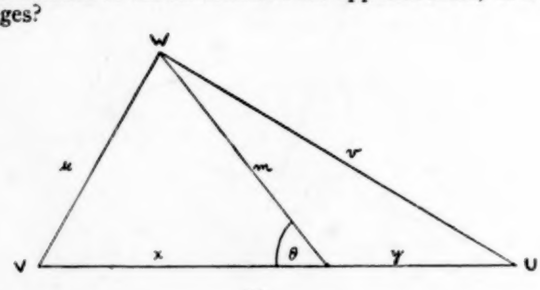
2:54:32 8/11, at which time the second hand is 10 10/11 degrees behind the required position,

and 9:05:27 3/11, at which time the second hand is 10 10/11 degrees ahead of the required position.

Also solved by W. E. Buker, Leetsdale, Pa.; Craig L. Smith, Missoula, Mont.; Francis Segesmau, Maryville, Mo.; Aaron Buckman, Brooklyn, N. Y.; and Roy MacKay, Albuquerque, N. M.

1333. *Proposed by Charles W. Trigg, Cumnock College, Los Angeles, Calif.*

What fundamental relationship exists between the medians (the lines joining the vertices to the centroids of the opposite faces) of a tetrahedron and its edges?



Solved by Aaron Buckman, Brooklyn, N. Y.

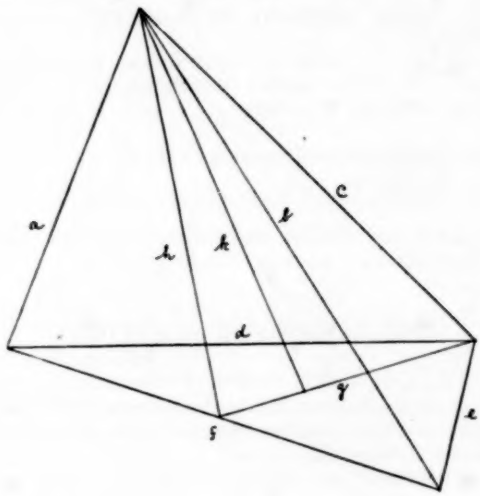
First two formulas for m^2 in $\triangle UVW$ will be stated. (m represents a median.)

These can easily be derived by use of the Law of Cosines, angle θ, and its supplement. See Figure 1.

$$\text{If} \quad x=y=\frac{w}{2}, \qquad m^2=\frac{u^2}{2}+\frac{v^2}{2}-\frac{w^2}{4}. \tag{1}$$

$$\text{If} \quad x=\frac{1}{3}w, \quad y=\frac{2}{3}w, \quad m^2=\frac{2u^2}{3}+\frac{v^2}{3}-\frac{2w^2}{9}. \tag{2}$$

Given tetrahedron with sides a, b, c, d, e, f (figure 2), h and g are medians to side f, k is a median of the tetrahedron.



$\therefore$ h and g bisect f.
$\therefore$ k divides g in the ratio 1:2.
Then to find h^2 and g^2 apply formula (1)

$$h^2=\frac{a^2}{2}+\frac{b^2}{2}-\frac{f^2}{4} \tag{3}$$

$$g^2=\frac{d^2}{2}+\frac{e^2}{2}-\frac{f^2}{4}. \tag{4}$$

And to find k^2 apply formula (2)

$$k^2=\frac{2h^2}{3}+\frac{c^2}{3}-\frac{2g^2}{9}. \tag{5}$$

Substituting (3) and (4) in (5)

$$k^2=\frac{a^2}{3}+\frac{b^2}{3}-\frac{f^2}{6}+\frac{c^2}{5}-\frac{d^2}{9}-\frac{e^2}{9}+\frac{f^2}{18}$$

3

$$k^2=\frac{a^2}{3}+\frac{b^2}{3}+\frac{c^2}{3}-\frac{d^2}{9}-\frac{e^2}{9}-\frac{f^2}{9} \tag{6}$$

$$k=\frac{1}{3}\sqrt{3(a^2+b^2+c^2)-(d^2+e^2+f^2)}. \tag{7}$$

Hence: The square of the median issued from a given vertex of a tetrahedron is equal to the arithmetic mean of the squares of the three edges

issued from the same vertex diminished by one-ninth the sum of the squares of the remaining edges.

Also solved by Balfour S. Whitney, University of Oklahoma, and H. Hansen Smith, Battle Creek, Iowa.

NOTE: Roy MacKay, Albuquerque, New Mexico, proves in addition to the above theorem, the following: The sum of the medians of a tetrahedron is less than two thirds and greater than four ninths of the sum of the edges of the tetrahedron.

HIGH SCHOOL HONOR ROLL

The editor will be very happy to make special mention of high school classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

For this issue the Honor Roll appears below.

1328, 29, 30. H. Hansen Smith, Battle Creek, Iowa.

1330. William Kent, Joy Jordan, and Emmett Durrum, all of the Lewis and Clark High School, Spokane, Washington.

PROBLEMS FOR SOLUTION

1346. *Proposed by T. A. Pickett, Boston, Mass.*

Lines drawn from the extremities of the base of a triangle, intersecting on the median to the base, cut the opposite sides at points which determine a line parallel to the base.

(Use only High School Geometry.)

1347. *Proposed by the Editor.*

If the sides of a quadrilateral are a, b, c, d, and if a pair of opposite angles are A and C, prove that:

$$(\text{Area})^2=(s-a)(s-b)(s-c)(s-d)-abcd\cos^2\frac{A+C}{2}.$$

Where $2s$ is the sum of the sides.

1348. *Proposed by Norman Anning, University of Michigan.*

Given that $b=\sqrt{2-\sqrt{2+a}}$ and that a is an approximation to the value of 2 sin 18°, prove that b is a better approximation.

1349. *Proposed by P. H. Nygaard, Spokane, Wash.*

```
          c d g
     ----------
e c ) c b e g e
      b k d
      -----
        h d g
        h k h
        -----
          k d e
          k d e
          -----
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396
83)32868
249
996
747
498
498

c > b
d > k > b

The above is a long division problem in which the digits have been replaced by letters. Each letter, wherever found, represents the same digit. Each digit, wherever found, is represented by the same letter. Determine which digit each letter represents, using a method which will show that no other solution is possible.

1350. *Proposed by Charles P. Louthan, Columbus, Ohio.*

A train dispatcher sends out three trains at h-hour intervals on parallel tracks. Each train travels at a uniform rate of speed from the starting point to the end of the trip, and all three reach the end of the line at the same time.

When the fastest of these trains has traveled one half of the time required to reach its destination, it is separated from the other two by distances of b and a miles respectively.

How far is the terminal from the starting point?

$\frac{2ab}{2b-a}$

1351. *Proposed by Cecil B. Read, Wichita, Kan.*

Given any four points, A, B, C, D in order on a straight line. Circles are described on the segments AC and BD as diameters, intersecting at P. Lines PA, PB, PC, PD are drawn. Prove that the angle BPC is complementary to one half the angle of intersection of the circles.

A SUPPLEMENTARY PROBLEM LIST

To show that mathematics has very vital connection with the world of concrete things a high school student, S. A. Husain, Lucknow, India, proposes the following problems. The Editor will not undertake to publish solutions unless some very important results should be obtained.

I. If one side of love is greater than another, prove that the angle of disappointment of the latter is more acute than that of the former.

II. Show how to describe a circle of friends, having given the centre of interest and some point of contact.

III. "If a person keeps two parallel friends, his alternate visits to each must be equal." Justify this statement.

IV. If there is a difference of opinion about a point between two persons show that they may go diametrically opposite to each other.

V. Establish and prove the following formulae of life:

"Simplify your wants, multiply your means, cancel your debts, square your budget, eliminate extremes and take simple interest in everything."

VI. Prove the following identity:

My wife was an addition, my children are multiplication, my death will be subtraction, and then there will be division among my survivors.

BOOK REVIEWS

The Biology of Bacteria, by Arthur T. Henrici, M.D., Professor of Bacteriology, University of Minnesota. An Introduction to General Microbiology. 482 pages, 112 figures. D. C. Heath and Company. $3.60. 1934.

This book has been written as a text to be used in a one-semester course for nontechnical college students; or as a basis for an introductory course for students who will pursue work in special courses along the line of applications of the science later. The author has carried out the principle that the elementary student should be grounded in the fundamental prin-

ciples of the science. To the student who understands the principles the applications will become obvious. It seems to the writer of this review that this is a stand which is well taken. The emphasis, even in books intended for high school use, has been placed entirely too much on the so-called practical applications before the student has any adequate view of the science. The book deals with microbe life, in general, including the protozoa, algae, fungi, bacteria, and filterable viruses, developing the subject of microbiology as a distinct science in itself, rather than as a branch of another biological science. Teachers of the biological sciences will appreciate the book as a reference for the easily understood discussions of subjects which the special texts usually give in a more technical manner. As a teacher of botany the writer is especially interested in the discussion concerning the metabolism of bacteria, particularly the soil bacteria. The book is an up-to-date concise statement of the principles of a science of which every person who claims to be well-informed must have some knowledge. From the examination of the text which the writer of this review could give it seems to be a unique contribution in its field.

JEROME ISENBARGER

How the World Lives and Works, by Albert Perry Brigham, Late Professor of Geology, Colgate University and Charles T. McFarlane, Formerly Professor of Geography, Teachers College, Columbia University. Cloth. Pages ix+406. 19×25 cm. 1933. American Book Company, 330 East 22nd Street, Chicago, Illinois.

A textbook for upper grades with a world point of view and intended to follow the work of the lower grades where the emphasis is placed on our own country and our near neighbors. The text is divided into three main sections. The first deals with the earth in space, time, seasons, weather, climate, maps, and graphs. This part is very complete and contains a wealth of information, much of which is of high school level. It is illustrated with many maps and diagrams.

The second section deals with the resources of the world and their use by man. Each chapter of this part presents one of the world's big industries, such as lumbering, fishing, agriculture, and manufacturing. Each industry is developed so as to show its historical importance, its location, based upon physical and climatic conditions, and its relation to other basic industries. This is the largest section and seems especially well adapted to the age for which it is intended.

The last section which presupposes an understanding of the other two, tells of the distribution of population and the interdependence of the nations.

One feature of the book which seems particularly good is the number of large and legible maps. Each chapter is supplied with many questions and tests written in a variety of forms which serve as a stimulus to independent thought. Teachers of grade school geography will want to inspect this new text.

H. S. TURNER

Signals and Speech in Electrical Communication, by John Mills, Author of *Within the Atom* and *Letters of a Radio Engineer to His Son*. Cloth. 281 pages, 12.5×19 cm. 1934. Harcourt, Brace and Company, Inc., 383 Madison Avenue, New York, N. Y. Price $2.00.

This is another one of the excellent science books you cannot afford to miss. It tells the story of the realization of a dream of the ages. Long distance communication like flying has been the theme of myth and fable since the dawn of history but only the present generation has witnessed

its accomplishment. It is not the purpose of the author to explain completely all the details of the telegraph, telephone, radio, television, etc. He presupposes considerable knowledge of the fundamentals of electricity, sound, and light and their application in electrical communication. He uses no diagrams or pictures but depends upon written language and common past experiences for conveying his meaning. Of this art he is a master. A door bell, a horse drawn cart, and Oscar of Century of Progress fame supply some of the common experiences.

One of the most interesting stories is the development of long distance telephony, first in 1911 by use of loading coils on the New York-Denver line and later in 1914 by means of vacuum tube repeaters on the extension of this line to San Francisco. Other chapters explain the transmission of pictures and television; their limitations and probable lines of future improvement are pointed out. Frequencies, modulation, howling, filters are the themes of other chapters. In the final section the author discusses the measurement of sound intensity and explains the limitations of the radio in reproducing original intensity of sound. To illustrate he describes the demonstration at the 1933 meeting of the National Academy of Science in reproducing orchestra music in auditory perspective and amplifying it beyond the original intensities.

G. W. W.

Electrons at Work, a Simple and General Treatise on Electronic Devices, their Circuits, and Industrial Uses, by Charles R. Underhill, Consulting Electrical Engineer. First Edition. Pages xii+354. Cloth. 14×22.5 cm. 1933. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, N. Y. Price $3.00.

For the general reader this book aims to supply the fundamental knowledge of electronics and present it in understandable form. The first seven chapters consist of foundation material including fundamental definitions and the explanations of such ideas as electric potential, capacity, electrons, ions, electric charges, the process of charging and discharging, dielectrics, condensers, magnetism, electromagnetism, direct and alternating currents. The student who has already mastered the basic ideas of electricity will prefer to begin his study with the discussion of electronic tubes. Here the author has done an unusually good job of explaining the construction, action, uses, and characteristics of the various types of tubes and their circuits. Electronic lamps and gaseous-discharge tubes are the subjects of other chapters. A brief discussion of light and color is introduced to support the chapters on photoelectric cells and their applications and the discussions of ultra-violet light and x-rays.

Throughout the book emphasis is placed on the applications of electronics in other science and especially in industry. It is rich in suggestions to executives and engineers for increasing efficiency and improving manufacturing and commercial processes. This book is a digest of much that has appeared on this subject in a number of engineering and scientific journals. It will be a great help to those who have not been able to keep abreast of the rapid development in this field.

G. W. W.

Unit Mastery Mathematics, by John C. Stone, Professor of Mathematics, State Teachers College, Montclair, New Jersey; Clifford N. Mills, Professor of Mathematics, State Normal University, Normal, Illinois, and Virgil S. Mallory, Associate Professor of Mathematics, State Teachers College, Montclair, New Jersey. Book One, pages v+314. Book Two, pages v+432. Book Three, pages v+469. 1934. Benj. H. Sanborn and Company.

This set of three textbooks is prepared for use in the Junior High School or for the corresponding grades in schools under the 8-4 plan. The authors state in the prefaces of the first two books that the guiding principles followed in writing the books were that the material be (1) easy to learn, (2) easy to teach and (3) interesting to pupils. A survey of the books indicates that although the material is largely conventional in type, the authors have followed these principles quite successfully.

Book One provides for continued practice and drill in the four fundamental operations with integers, decimals and common fractions. The meaning and use of per cent is introduced and is applied in lessons in thrift and the arithmetic of business. The latter part of the book is devoted to intuitive geometry and various types of graphs. Book Two reviews and extends the work on measuring surfaces, measuring solids, and per cent. The formula and the solution of linear equations are introduced in the first chapter. No further use is made of the equation except at the end of the book. A major portion of the material may be classed as social arithmetic. The topics covered include banking, thrift, investing money, insurance and taxes. This material is up-to-date and interesting. An illustration is the teaching of a method of computing the interest paid on money in the case of installment purchases. Many problems are furnished. Certainly this material represents an effort to assist the pupil in developing his power to think quantitatively. The latter part of the book treats the topics ratio and proportion, similar figures, and square root.

Book Three provides a complete course in first year algebra. An effort is made to integrate the use of the graph, formula, and equation. The truths of intuitive geometry are used to provide problem material for work on the formula and equation. Training in functional thinking receives specific attention in a few places in the book. An introduction to elementary trigonometry and to demonstrative geometry is provided in the latter part of the book.

Each of the books contains a wealth of simple practice material, graded as to difficulty. Provision for individual differences is made by using a line to set off the more difficult exercises. The review exercises and tests included should serve as an aid in teaching. The style of the page, the drawings and the binding all combine to make the books attractive.

G. E. Hawkins

BOOKS RECEIVED

Exercises in First Year Algebra, by George K. Sanborn, Instructor at Phillips Academy, Andover, Massachusetts. Cloth. 148 pages. 12.5×18.5 cm. 1934. American Book Company, 330 East 22nd Street, Chicago, Illinois.

Mathematics Essential for Elementary Statistics, by Helen M. Walker, Assistant Professor of Education, Teachers College, Columbia University. Cloth. Pages xiii+246. 12.5×18.5 cm. 1934. Henry Holt and Company, One Park Avenue, New York, N. Y. Price $1.50.

Beginner's Steps in Arithmetic, Grade I, by Bennett, Conger and Conger. Paper. 112 pages. 20×28 cm. 1933. American Book Company, 330 East 22nd Street, Chicago, Illinois.

Beginner's Steps in Arithmetic, Grade II by Bennett, Conger, and Con-

ger. Paper. 144 pages. 20×28 cm. 1934. American Book Company, 330 East 22nd Street, Chicago, Illinois.

The Teaching of Biology, by William E. Cole, Associate Professor of Science Education in the University of Tennessee. Cloth. Pages xiv+252. 12.5×18.5 cm. 1934. D. Appleton-Century Company, Inc., 35 West 32nd Street, New York, N. Y. Price $2.00.

Junior Mathematics for Today, Book Two, by William Betz, Vice-Principal of the East High School and Specialist in Mathematics for the Public Schools of Rochester, New York. Cloth. Pages x+438. 12.5×19 cm. 1934. Ginn and Company, 15 Ashburton Place, Boston, Massachusetts. Price 96 cents.

Progressive First Algebra, by Walter W. Hart, Associate Professor of Mathematics, School of Education, and Teacher of Mathematics, Wisconsin High School, University of Wisconsin. Cloth. Pages vi+408. 12×19 cm. 1934. D. C. Heath and Company, 285 Columbus Avenue, Boston, Massachusetts. Price $1.28.

Progressive Second Algebra, by Webster Wells, Author of a Series of Texts on Mathematics and Walter W. Hart, Associate Professor of Mathematics, School of Education and Teacher of Mathematics, Wisconsin High School, University of Wisconsin. Cloth. Pages v+298. 12×19 cm. 1934. D. C. Heath and Company, 285 Columbus Avenue, Boston, Massachusetts. Price $1.32.

Biology for Today, by Francis D. Curtis, Head of the Department of Science, University High School, and Professor of the Teaching of Science, University of Michigan; Otis W. Caldwell, Professor of Education and Director of the Institute of School Experimentation, Teachers College, Columbia University; Nina Henry Sherman, Teacher of Biology, University High School, Ann Arbor, Michigan. Cloth. Pages xvi+692+xxv. 13×20 cm. 1934. Ginn and Company, 15 Ashburton Place, Boston, Massachusetts. Price $1.76.

Exploring the World of Science, by Charles H. Lake, Superintendent of Schools and formerly Principal of East Technical High School, Cleveland; Henry P. Harley, Supervising Teacher of Science, Fairmount Junior High Training School, Cleveland; Louis E. Welton, Assistant Principal and Formerly Head of Science Department, John Hay High School, Cleveland. Cloth. Pages ix+692. 13×19.5 cm. 1934. Silver, Burdett and Company, 39 Division Street, Newark, N. J. Price $1.76.

The Story of Energy, by Morton Mott-Smith, Author of *This Mechanical World, Heat and Its Workings*, etc. Cloth. Pages xii+306. 12.5×19 cm. 1934. D. Appleton-Century Company, 35 West 32nd Street, New York, N. Y. Price $2.00.

Plane Geometry, by Joseph P. McCormack, Head of the Department of Mathematics in Theodore Roosevelt High School, New York City. Revised Edition. Cloth. Pages xiv+455. 12.5×19 cm. 1934. D. Appleton-Century Company, 35 West 32nd Street, New York, N. Y. Price $1.40.

Unit Mastery Mathematics, by John C. Stone, Professor of Mathematics, State Teachers College, Montclair, New Jersey; Clifford N. Mills, Professor of Mathematics, State Normal University, Normal, Illinois; Virgil S. Mallory, Associate Professor of Mathematics, State Teachers

College, Montclair, New Jersey. Cloth. 13×19 cm. Book I, pages v+314. Price 96 cents. Book II, pages v+432. Price $1.00. Book III, pages v+469. Price $1.20. 1933. Benj. H. Sanborn and Company, 221 E. 20th Street, Chicago, Ill.

Strayer-Upton Practical Arithmetics, by George Drayton Strayer, Professor of Education, Teachers College, Columbia University and Clifford Brewster Upton, Professor of Mathematics, Teachers College, Columbia University. Cloth. 12.5×18 cm. First Book, pages viii+500. Second Book, pages viii+500. 1934. American Book Company, 330 East 22nd Street, Chicago, Ill.